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REPORT OF THE AD HOC WORKING GROUP ON INNOVATIVE MOBILITY CONCEPTS

Robert Ehrlich, et al

Stevens Institute of Technology
Hoboken, New Jersey

October 1973

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Dr. I. Robert Ehrlich, Stevens Institute of Technology, Chairman
LTC Franklin Cantwell, Headquarters, U.S. Army Materiel Command
Mr. James Carr, Headquarters, U.S. Army Materiel Command
Mr. Howard Dugoff, U.S. Army Tank-Automotive Command
Mr. Adam Rula, U.S. Army Engineer Waterways Experiment Station
Mr. Clifford J. Nuttall, Jr., U.S. Army Engineer Waterways Experiment Station

It was the responsibility of this Steering Committee to plan and organize the sessions, to select and invite the attendees, to outline the content of the briefings, to obtain the briefers, to make all the administrative, housing and special arrangements, and to prepare this written report of the Workshop results.

The body of this report concentrates on the most significant ideas suggested by the Workshop. To develop these particular ideas further than was possible (or considered desirable) in the Workshop sessions, a two-day "idea improvement meeting" was held on 22-23 May 1973, at St. Clair, Michigan. The discussions which follow accordingly reflect the deliberations not only of the workshop attendees, but also of the participants at the St. Clair meeting. Administrative and organizational details, lists of attendees at both the Durham and St. Clair meetings, plus a complete listing of all ideas formulated, are included in the appendices for completeness.

DAVIDSON LABORATORY
Stevens Institute of Technology
Castle Point Station
Hoboken, New Jersey 07030

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October 1973

REPORT OF THE AD HOC WORKING GROUP ON INNOVATIVE MOBILITY CONCEPTS

Held at
Durham, North Carolina
17-20 October 1972

and

St. Clair, Michigan
22-23 May 1973

by

I. Robert Ehrlich, Chairman
Frank Cantwell
James Carr
Howard J. Dugoff
David Latson
Augustus Magistro
Clifford J. Nuttall, Jr.
Ronald Patek
Adam A. Rula

Sketches by Paul Spansky

Approved by:

iia.

I. Robert Ehrlich, Chairman

TABLE OF CONTENTS

LIST OF FIGURES v

FORWARD vii

PREFACE ix

I. SUMMARY 1

II. INTRODUCTION 3

Objective 3

Scope 3

Approach 3

Discussion 4

III. RESULTS 7

A. Wheel Systems 7

B. Remote Controlled Vehicles 14

C. Driver Aids 15

D. Vehicle Form and Operational Concepts 20

E. Propulsion Concepts 36

F. Flotation and Traction Aids 41

G. External Mobility Aids 44

H. Software Ideas 50

IV. CLOSURE 56

APPENDIX A - ORGANIZATIONAL DETAILS AND METHODOLOGY

APPENDIX B - PARTICIPANTS

APPENDIX C - INSTRUCTIONS FOR WORKSHOP

APPENDIX D - TEAM CHAIRMAN'S ORIENTATION

APPENDIX E - BRIEFING DOCUMENT

APPENDIX F - CHARACTERISTICS OF VARIOUS TERRAIN OBSTACLES

APPENDIX G - DETAILED TEAM IDEAS

APPENDIX H - MASTER AGENDA

LIST OF FIGURES

1 IF WHEELS WERE PROPERLY DESIGNED, THEY COULD EASILY BE ATTACHED TO PROVIDE INCREASED FLOTATION AND TRACTION 8

2 CENTRAL TIRE INFLATION SYSTEMS, WITH SIMPLE CONTROLS, WILL MATERIALLY IMPROVE THE MOBILITY OF WHEELED VEHICLES . . 10

3 EXAMPLES OF NON-CIRCULAR WHEELS. A CONICAL WHEEL (TOP); AN ELLIPTICAL WHEEL (MIDDLE); A SPIRAL WHEEL (BOTTOM). . . . 11

4 VEHICLES, CONTROLLED FROM REMOTE, SECURE LOCATIONS COULD PERFORM HAZARDOUS MISSIONS 13

5 A MARRIAGE OF THE GROUND VEHICLE WITH THE HELICOPTER WILL PROVIDE THE SOLDIER MOBILITY AFTER PLACEMENT ON THE BATTLEFIELD 21

6 ARTICULATED VEHICLES HAVE THE ADVANTAGE OF BOTH INCREASED MOBILITY ON THE GROUND AND INCREASED TRANSPORTABILITY IN THE AIR 22

7 THE ARTICULATED TANK DESCRIBED IN THE TEXT OFFERS MANY OPERATIONAL ADVANTAGES 23

8 FOLDABLE WHEELS WOULD BE STORED WHEN NOT NEEDED (TOP) BUT INFLATED FOR SOFT TERRAIN (BOTTOM). FOLDABLE WHEELS WOULD BE POWERED BY SMALL IDLER WHEELS 24

9 TRUCKS, SPECIFICALLY DESIGNED TO BE COUPLED TOGETHER TO FORM TRAINS. PRIME UNIT (TOP) COULD COUPLE TO OTHER PRIME UNITS OR TO CHEAPER SECONDARY UNITS TO FORM TRAINS (LOWER TWO SKETCHES) 25

10 MODULAR COMPONENTS COULD EASILY BE ASSEMBLED TO A VARIETY OF FRAMES TO FORM MANY DIFFERENT VEHICLE CONFIGURATIONS . . 27

11 A POWERED, LIMP CHAIN, HANGING FROM AN AIR CUSHION VEHICLE COULD PROVIDE THE TRACTION NECESSARY TO GENERATE ADDITIONAL CONTROL AND SLOPE CLIMBING ABILITY 30

12 SPRING LOADED "PIZZA CUTTERS" WOULD PROVIDE POSITIVE LATERAL CONTROL FOR CROSS-SLOPE OPERATION 31

13 DIVIDING THE ROTORS IN TWO AND ALLOWING THEM TO STEER WOULD PROVIDE CRABBING ABILITY AND IMPROVED OPERATION ON FIRM SURFACES 32

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List of Figures

14 AMONG THE HYBRID VEHICLES CONSIDERED WAS THAT OF MARRYING THE TRACK WITH AN AIR CUSHION TO NEGOTIATE SOFTER TERRAIN . . 34

15 DIRECT USE OF THE COMBUSTION GASES TO INFLATE AND DEFLATE CIRCUMFERENTIALLY SEGMENTED TIRE CHAMBERS COULD ELIMINATE THE ENGINE-TRANSMISSION-DRIVE LINE SYSTEM 37

16 A LINEAR INDUCTION MOTOR COULD DRIVE A METAL IMPREGNATED BAND TRACK WITHOUT THE DRIVE-LINE AND GEAR SYSTEMS REQUIRED OF CONVENTIONAL TRACKS 39

17 IN A MANNER SIMILAR TO THAT SHOWN IN FIGURE 16, A LINEAR INDUCTION MOTOR CO LD DRIVE A STEEL-BELTED TIRE 39

18 TRACK SHOES, WHICH ARE DESIGNED TO YIELD TO IMPOSED STRESSES, RATHER THAN TO RESIST THEM, COULD MATERIALLY LIGHTEN TRACK DESIGN 42

19 A WATER JET, POWERED BY COMPRESSED AIR OR EXHAUST GASES, COULD PROVIDE SHORT-TERM AUXILIARY THRUST WHILE OVERCOMING OBSTACLES 43

20 TO MAINTAIN ROPE CONTACT WITH THE CAPSTAN WHEN THE TRACKS BEGIN TO GRAB, THE CAPSTAN DIAMETER MUST BE GREATER THAN THE PITCH DIAMETER OF THE DRIVE SPROCKET 44

21 A PLASTIC BUBBLE WOULD ALLOW A FOOT SOLDIER TO "WALK ON WATER." SUCH A DEVICE IS PRESENTLY IN USE FOR RECREATIONAL PURPOSES . 46

22 VEHICLE-MOUNTED EXCAVATION DEVICES, SUCH AS A BACK-HOE OR FRONT-END LOADER, COULD BE USED TO REDUCE OBSTACLES AS WELL AS AID MOBILITY BY PROVIDING ADDITIONAL PUSHING FORCES. . . . 47

23 A HIGH-PRESSURE HOSE, MOUNTED ON AN AMPHIBIAN, COULD BE USED TO REDUCE RIVER BANKS TO A MANAGEABLE SLOPE 48

24 IN WORLD WAR I, TANKS CARRIED BUNDLES OF STICKS OR FENCING TO HELP BRIDGE TRENCHES. SIMILAR DEVICES COULD STILL BE UTILIZED 50

25 PROPERLY CONTOURED LAUNCH AND RECAPTURE RAMPS WOULD AID VEHICLES IN CROSSING SHORT GAPS (ABOVE). CARE MUST BE TAKEN TO CONTROL LAUNCH SPEED TO MATCH RAMP CONTOUR AND GAP DISTANCE TO AVOID CATASTROPHY (BELOW) 51

FORWARD

During 17-20 October 1972, a workshop to identify, conceive and examine possible concepts and approaches for materially increasing the Army's ground mobility was held in Durham, North Carolina, at the behest of the Office of the Director of Defense Research and Engineering (ODDRE) who charged the Army Materiel Command (AMC) with the responsibility of implementing their request. AMC, in turn, assigned the task to a committee comprised of:

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PREFACE

A great deal remains to be done in the technology of surface movement, as proven in Vietnam. Major advances in other technologies, especially in weaponry, have brought the need for almost revolutionary improvements in surface mobility. It was the principal objective of this Workshop to explore the availability of innovative ideas by which Land Mobility might be substantially improved.

When one implements innovations, many factors must be considered carefully and quantitatively. Realistic systems analysis is required of the ability of each new concept to perform. How does this concept fit into the overall strategy and force structure? Is the concept attractive enough to warrant modification of the present way of doing business, and the present operations doctrine? Does it have such merit that drastic changes should be made to accommodate it? As important as these considerations are, they had little place at this Workshop--innovative ideas were to be set down--later, judgments would be made of their utility.

The group whose ideas are represented by this report was overwhelmingly an experienced surface mobility group. The several presentations made during the week were strongly influenced by the status quo. I had originally suggested that we bring together a group totally unrestricted by the multiplicity of forces shaping our present surface mobility activities. Would such a group, given specific missions and limitations to current capabilities, have arrived at solutions of value to present users of mobility technology? I am certain that many radical solutions would have been proposed had a Workshop group been almost totally composed of people outside the land mobility community. I have much less confidence, however, that their ideas would have been useful. I shall perhaps continue to wonder, just a little, about the effect of experience on innovation and the ideal construction of any future Workshop.

My personal retrospection notwithstanding, Dr. Ehrlich and the participants of this Workshop are to be commended for a difficult job well done. The group worked very hard and accomplished the Workshop objectives. I extend to all involved my very sincere thanks.

It seems clear from this report that major opportunities exist. As Greg Bekker put it, "now like the Fiddler on the Roof, we can dream of what we would do if we were very, very rich." A major selling task faces those of us who are interested in advancing the technology of Land Mobility. Perhaps most important is the need to document our belief that there are ideas, innovations, unexplored and unexploited areas, and older ideas whose time has come, which users of this technology should be eager to see developed and employed. Just how our community can best move forward to sell and exploit these ideas should perhaps be the topic for another Workshop.

ROBERT W. ZIEM
Office of the Director
of Defense, Research
and Engineering

I. SUMMARY

The principal objective of the Workshop was to generate ideas for improvement of mobility hardware, i.e., vehicles, which might see service in the period 1980-1990 and beyond. The Workshop attendees included Department of Defense experts in military vehicles and mobility, technical personnel from civilian life known to be innovative in their thinking and accomplishments, and non-technical individuals.

More than six hundred ideas emerged from brainstorming sessions of six teams, each composed of six to eight members. Of these ideas, approximately one hundred were deemed worthy of highlighting in the main body of this report. These have been organized into eight general categories:

A. Wheel Systems.

The mobility potential of wheeled systems has not been fully exploited. New approaches to tire design, wheel form, and wheel application will yield significant increases in mobility at reasonable costs.

B. Remote-Controlled Vehicles.

New developments in telemetry, developed under the N.A.S.A. space program, make the use of remotely-controlled vehicles in certain hazardous missions technically and economically feasible.

C. Driver Aids.

The driver is a neglected key element in operational mobility. Design features to facilitate the driving task and/or improvements in driver training procedures have great potential to improve driver/vehicle performance.

D. Vehicle Form and Operational Concepts.

Strong recommendations were made for greater exploitation of the articulated vehicle form and for closer air/ground vehicle systems integration to provide effective ground transportation for airlifted combat troops, once they debark from their helicopters.

E. Propulsion Concepts.

Concepts were proposed to make more efficient use of fuel energy by the direct conversion of that energy at the soil-vehicle interface, to develop alternate and synthetic fuels for use in the event of an interruption in our petroleum supply, and to make greater use of electric drive systems, especially the linear induction motor.

F. Flotation and Traction Aids.

A number of different concepts were presented that have potential materially to improve vehicle soft soil performance by increasing traction or decreasing ground pressure.

G. External Mobility Aids.

Some simple, novel techniques which could aid vehicle mobility by modifying the terrain, anchoring into the terrain, or aiding flotation in water were suggested.

H. Software Ideas.

Recommendations were made for the development of new software, or methodology, to provide order and direction to proposed hardware activities and, more generally, to develop a rational, objective basis for decisions relative to the design and procurement of land mobility systems.

II. INTRODUCTION

Objective

The objectives of the Workshop were to review the state of ground mobility technology and to identify possible concepts and approaches for materially increasing the Army's ground mobility for the period 1980-1990 and beyond. The basic aim was to conceive innovative hardware ideas, not to develop workable systems.

Scope

The hardware ideas were to relate to the movement of vehicles off roads, cross country, and on unimproved roads and trails. Only combat (fighting) and tactical vehicle concepts were to be considered. Thus, the following subjects, important in the overall aspects of mobility, were excluded:

a. Aircraft
b. Ships
c. Amphibious vehicles
d. Containerization
e. Non-vehicle logistic systems (pipelines, fixed rails, monorails, conveyors, tramways)

The scope of the effort was limited to the identification of ideas which, when implemented, would ostensibly cause a direct and measurable improvement in the performance of a combat or tactical vehicle in at least one mobility situation. Considerations of feasibility, practicability, cost, etc., or of implementation of the ideas was not permitted to inhibit their generation.

Approach

To achieve the objectives stated above, first the brainstorming technique, which aims at generating a large number of unevaluated ideas, was utilized (see Appendix A) at a Workshop held in Durham, N. C. The

participants included DOD experts in the field of automotive vehicles, personnel from civilian industry who were known to be technically innovative in their thinking and accomplishments, and non-technical individuals who, by their innocence, would cause the workshop to think in new directions (see Appendix B).

The most promising ideas generated in the Durham brainstorming sessions were then developed further in an "Idea Improvement Session" held at St. Clair, Michigan. Participants at this later session were limited to military officers and DOD civilian engineers. The material which follows represents the combined results of the two efforts.

Discussion

Mobility means many things to many people. Each person sees it in the light of his own knowledge and experience. The term mobility is defined in AR 310-25 as: "A quality or capability of military forces which permits them to move from place to place while retaining the ability to fulfill their primary mission." The same document defines mobile warfare as: 'Warfare of movement in which the opposing sides seek to seize and hold the initiative by use of maneuver, organization of fire and utilization of terrain."

For the purposes of this workshop, a combat vehicle was defined as: "A vehicle, with or without armor, designed for a specific fighting function." A tactical vehicle was defined as: "A vehicle with military characteristics designed primarily for use by forces in the field in direct connection with, or support of, combat or tactical operations." The emphasis was on off-road, cross-country operations.

The trend in recent years in the field of ground mobility has been toward product improvement through a program of modification and modernization. This approach is perhaps appropriate from a short-range viewpoint. However, the fact that most of the Army's present fleet was built with 1950-60 state-of-the-art and will be 20 to 30 years old by 1980, suggests that recent advances in technology must be exploited for new and improved mobility systems that will provide the U.S. combat soldier of the future with a tactical advantage.

There are many aspects of mobility. Early mobility research identified and studied in depth the soft soil problems. Many people, when they think of a "highly mobile" vehicle still envision one slogging through deep mud. Current understanding, however, recognizes many other important aspects of mobility. There is the rough terrain problem which, while it presents little potential for immobilization, severely limits the speed of the vehicle. There is also the problem of negotiating obstacles such as fallen trees, ditches, banks, rocks and man-made impediments.

Rivers place a severe restriction on ground vehicle operations. In highly developed countries, most rivers are bridged at all essential and convenient places to the extent that, in peace time, they are rarely considered an impediment to movement. However, in less developed nations or in an unlimited war, we can expect but few bridges to exist, and those that do exist to be of but limited capacity. Hence, the ability to cross rivers is an important consideration in mobility. And river crossing is more than just swimming; it is entrance into the water, negotiating the land/water interface, propulsion and control in the current, and exiting at the far side.

Control has only recently been recognized as a mobility factor. A vehicle which is easy to control and has good handling qualities allows its operator and crew to function better, to move more surely and to maneuver well. Hence, control and the man/machine/environment constitute another facet of mobility.

Armor protection becomes an aspect of mobility when it permits selection of routes which would be denied to a thin-skinned vehicle.

Communications are also related to mobility, for they facilitate coordinated movement and the exchange of information relative to route conditions.

Last, but by no means least, is RAM-D (reliability, availability, maintainability and durability), for a vehicle which is deadlined is just as immobile as one stuck in the mud.

Thus, there are many aspects of mobility which we have been able to identify. In a given situation, we can overcome any of these by one technique or another. We can go anywhere we please for a price. But to deal with all possible mobility problems with a single vehicle would be prohibitively expensive. Thus, the "mobility problem" is to go in as many important areas as possible at a minimum complexity and cost. The definitions of the two underlined words, "important" and "minimum" become the center of focus. How do we define "important" and what can we afford?

The basic approach in the Workshop was to develop totally new ideas or approaches towards improved mobility. However, since new ideas are not easily generated, a look was taken at new applications of old ideas, at old ideas in the light of newly developed or soon to be expected technology, and at old ideas that may not have been fully tested or evaluated.

III. RESULTS

The ideas for the improvement of Army ground mobility generated in brainstorming sessions numbered more than six hundred, an average of more than one hundred per team. (There were, of course, many cases of duplication or close similarity.) All ideas generated by each of the six teams are contained in the respective sections of Appendix G.

Following the brainstorming sessions, each team was asked to review its own ideas, to select and to amplify the "best" ten. Each team selected its own criteria for evaluation. Some teams, being more enthusiastic (or less disciplined) selected more than ten. Hence, from the six teams, approximately one hundred ideas finally emerged.

In general, the ideas reflected attempts to get more out of the wheel, to get more out of the driver, to supplement vehicle capabilities and to modify the terrain environment. Many ideas also reflected complete systems concepts and methodology. For convenience, these ideas were subdivided into eight, not always mutually exclusive categories.

A. Wheel Systems

There was a strong feeling among participants that the mobility potential inherent in the wheel form has not been fully exploited. New approaches to tire design, wheel form, and wheel application will yield significant increases in mobility at reasonable costs.

1. Expedient Dualing of Wheels

An inexpensive, yet effective, concept is to design vehicles so that additional wheels can be added by a simple bolt-on or clamp-on process to "dual up" the wheels when operation in soft soils is expected (see Figure 1). Thus, single tires can quickly be converted into duals; duals into triples; etc. Extra wheels can be obtained from spares carried on other vehicles, from the motor pool, or from disabled vehicles.

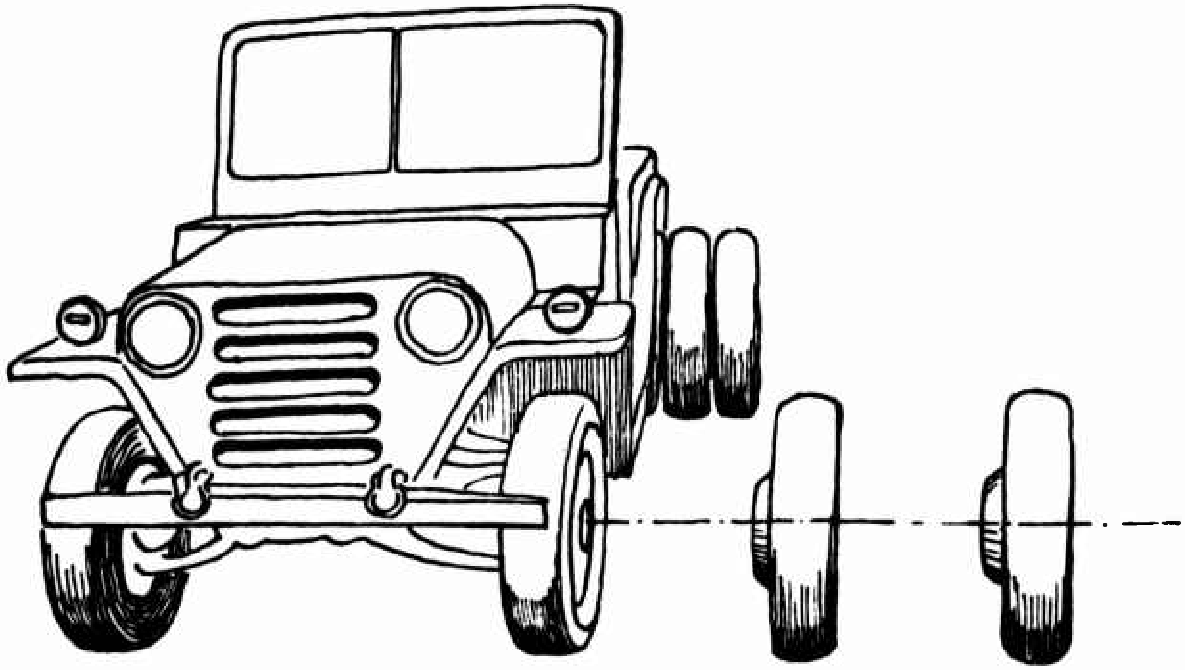

FIGURE 1. IF WHEELS WERE PROPERLY DESIGNED, THEY COULD EASILY BE ATTACHED TO PROVIDE INCREASED FLOTATION AND TRACTION

Alternatively, special, folding, lightweight tires on lightweight plastic rims could be developed for this purpose and carried on the vehicle without appreciable weight or space penalty. Since their use would be short-term only on soft soils, wear and heat problems would be minimal. These extra tires might be one-piece, low-cost, throw-away units.

To accommodate this concept, fenders must be appropriately designed and drive lines made capable of withstanding the added torque and cantilevered loads.

2. Variable Geometry Wheels

Much of the mobility capability of the conventional pneumatic tire stems from the fact that it varies its shape in relation to the applied load and inflation pressure. The ideas presented here are to extend further this characteristic.

The most immediate approach is to vary tire pressure to suit operating conditions--low pressure for high deflections in the off-road environment, higher pressures on the highway to avoid heat buildup and to achieve satisfactory handling at road speeds. Operationally, this requires some form of central tire inflation control, either automatic or manual, with simple, predetermined, labeled settings (see Figure 2). A central inflation control system was used on the DUKW of World War II with much success. Tire inflation control systems are currently in use or planned for the military trucks of most Warsaw Pact countries. Their use on the Russian 2-½ ton and 3-½ ton trucks make these vehicles more mobile than ours.

New tire technology, especially with radial designs, makes possible tires which are less sensitive to heat buildup and hence can be exploited to develop military tires with greatly extended ranges of deflection under central inflation control.

Another approach is to make the wheel itself deformable. The idea of designing a wheel which changes shape as it turns, thus generating the ground contact surface of a much larger wheel, is not new. Devices such as those designed by Markow (spiral wheel, cone wheel) or Liston (elliptical wheel), singly or combined with a pneumatic tire should be investigated (see Figure 3).

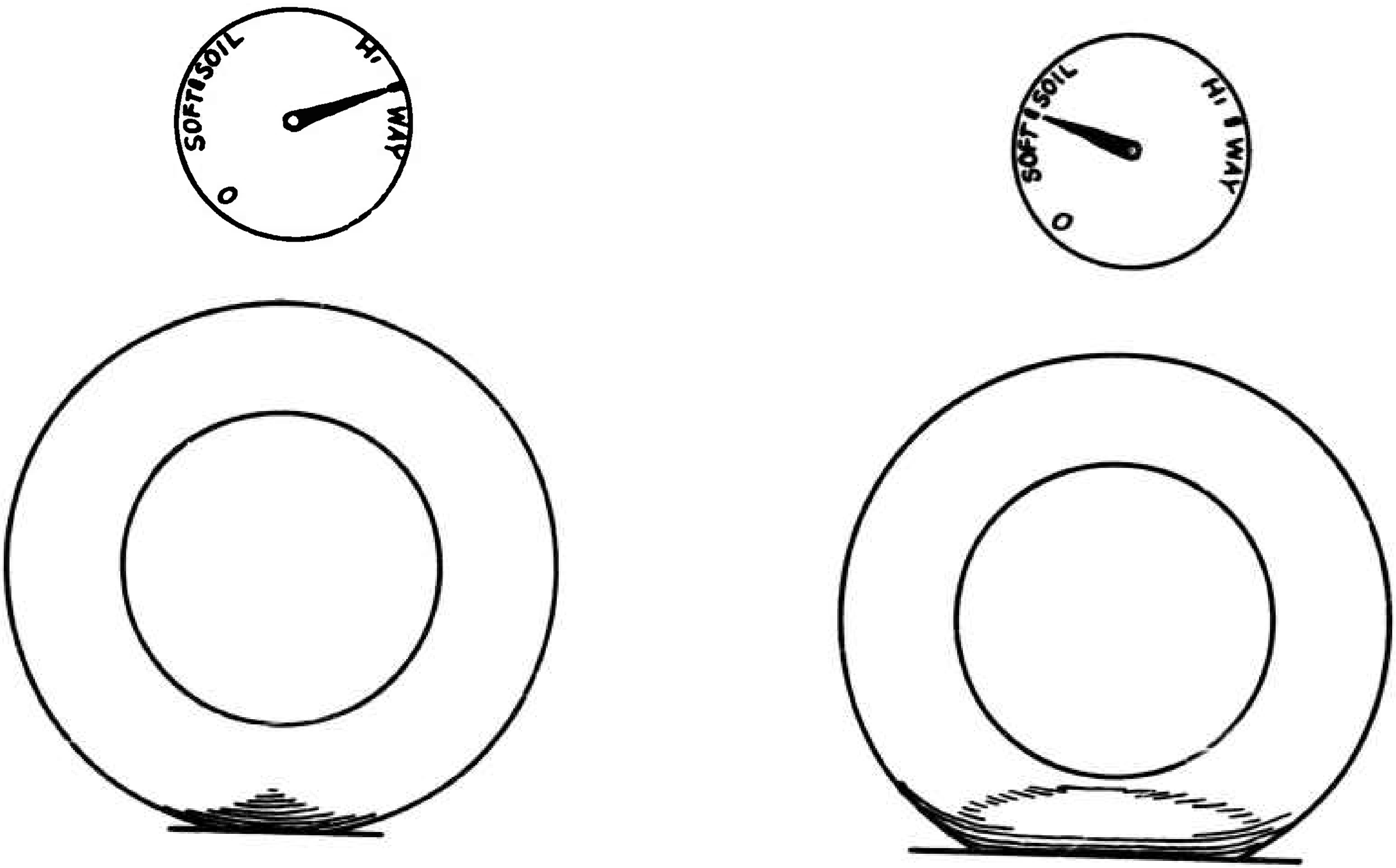

FIGURE 2. CENTRAL TIRE INFLATION SYSTEMS, WITH SIMPLE CONTROLS, WILL MATERIALLY IMPROVE THE MOBILITY OF WHEELED VEHICLES.

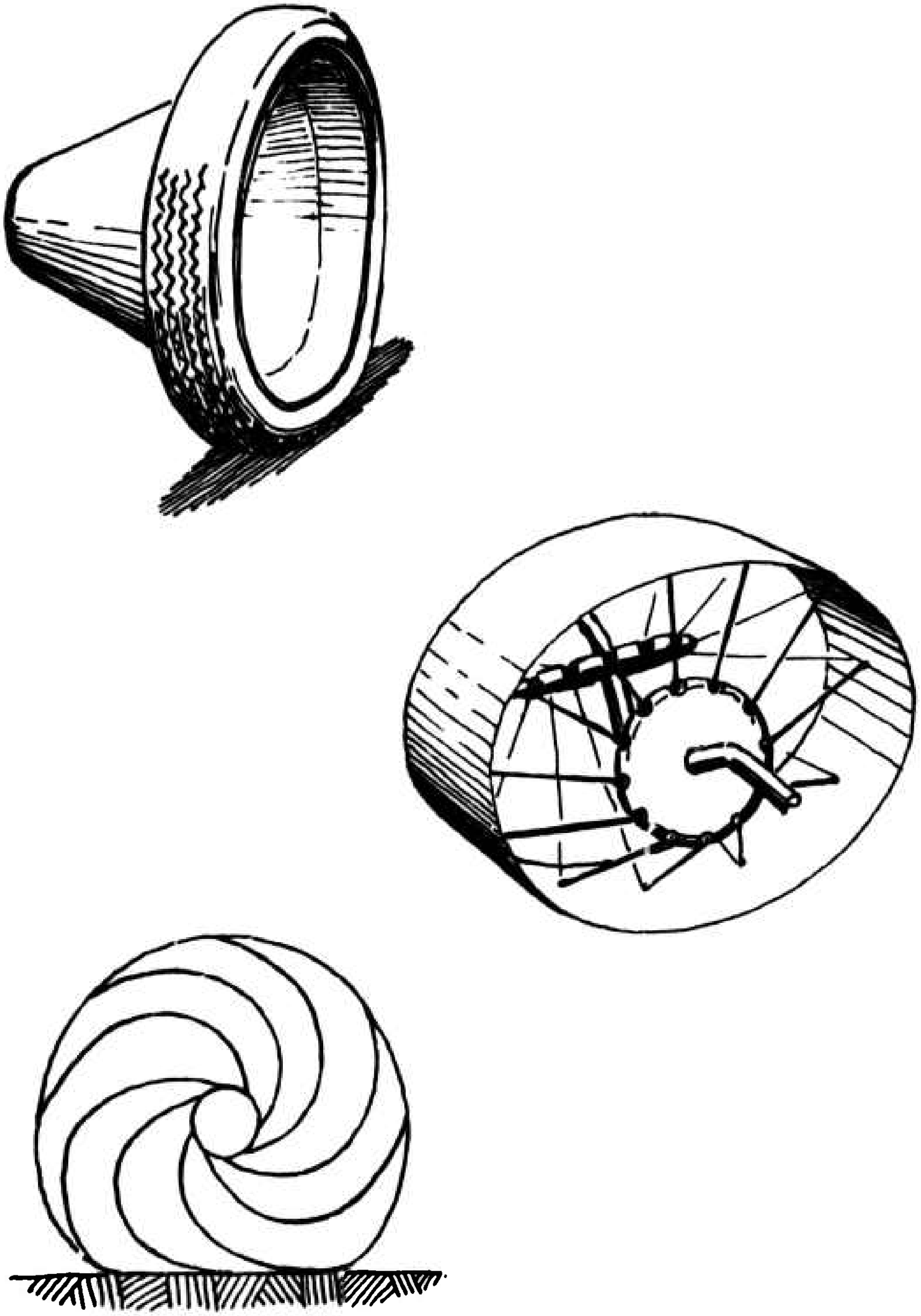

FIGURE 3. EXAMPLES OF NON-CIRCULAR WHEELS.
A CONICAL WHEEL (TOP); AN ELLIPTICAL WHEEL (MIDDLE);
A SPIRAL WHEEL (BOTTOM).

3. The Tire as a Suspension Element

The pneumatic tire is itself a spring. There are obvious advantages in using the tire as the principle suspension element. One approach is to configure the wheel itself as a spring and damper system. By varying pressure, the spring rate can be changed in accordance with load and terrain. Conventional tires, however, have neither sufficient damping nor deflection properties to maximize this possibility. By placing chambers within the tire to restrict internal air flow, greater damping characteristics could be obtained. Tire pressures can be varied to detune vehicle response to input vibrations. Here again, central inflation control would be a key element.

4. Damage-Proof Tires

Pneumatic tires provide excellent ride and control properties. However, they are highly susceptible to damage from enemy fire and off-road hazards. Army vehicles, especially those designed for combat missions, badly need a damage-proof tire. Present foam-filled concepts have not proved successful because of heat buildup due to the hysteresis from flexing and the excellent insulating properties of the foam. A foam which has low hysteresis properties and/or is a good conductor of heat would hold up better. Flexible supporting structures other than pneumatic chambers should also be investigated.

Run-flat capabilities should be extended. Tires which fold within the rim, hence are still marginally usable, have promise. So do dual concentric chambers.

A cartridge which injects a foam or gas to seal a break and reinflate the tire is also a possibility. Such a system could be manually operated or triggered from the change in air pressure or temperature that would occur at or near failure.

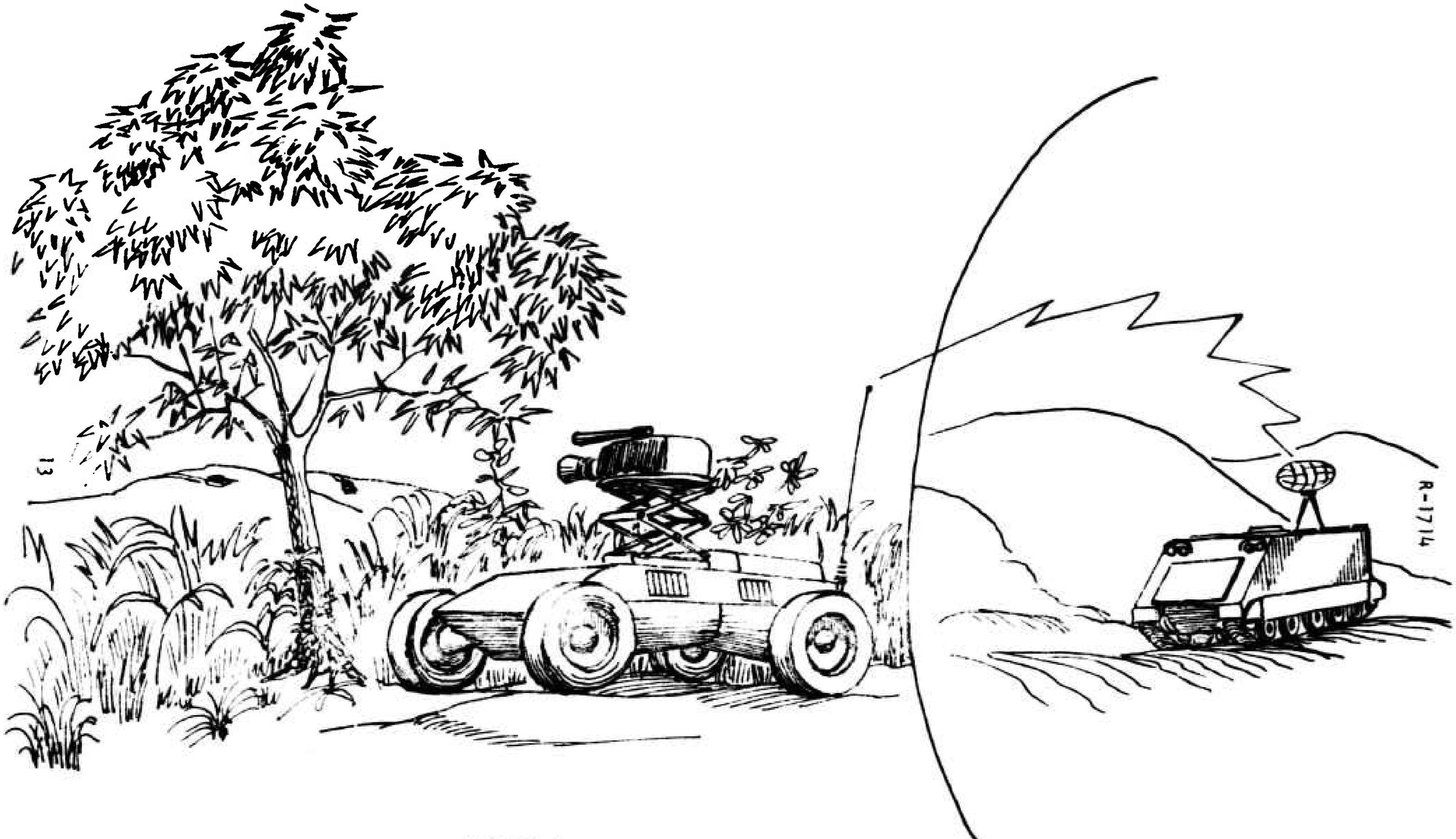

FIGURE 4. VEHICLES, CONTROLLED FROM REMOTE, SECURE LOCATIONS COULD PERFORM HAZARDOUS MISSIONS.

B. Remote Controlled Vehicles

Many of the teams suggested roles in which remote control could be exploited to aid mobility. The applications proposed included combat, reconnaissance and traction aid. Remotely controlled vehicles (RCV's) can isolate the soldier from potential danger when operating in radioactive areas, probing roads and areas suspected of mines and booby traps, designating targets and aiding or retrieving damaged combat vehicles. RCV's can also be put through maneuvers that man cannot tolerate. Taking personnel from such vehicles reduces space, armor and suspension requirements and hence permits reduction in size, weight and automotive complexity.

Direct mobility applications suggested were:

- o A small, highly mobile, scout or lead vehicle, radio-controlled by a human operator in a following vehicle to send back TV or sensor readings to following personnel.
- o Remotely controlled trailmarker or pioneer vehicles (see Section D5).
- o Remotely controlled daughter unit of a two-element combat vehicle (see Section D2).
- o Remote controls in the local sense would allow the crew of a manned combat vehicle to be grouped in a single, compact, highly protected region of the vehicle, leaving the less vulnerable components exposed or only lightly protected. Protecting only vital components would greatly lighten the armor required.

With the great recent advances in integrated circuitry, more rugged television cameras and transmitters, and more sophisticated control circuitry and techniques, the electronic componentry for RCV's can be made relatively inexpensive and reliable. Combined with changes in vehicle form, this approach opens the way to relatively inexpensive, mass-produced vehicles. In the combat role, low cost will permit greater expendability and greater numbers, which could provide battlefield superiority. For combat, as for other applications, the effective ex-

ploitation of RCV's will obviously require the development of radically new tactics and doctrine.

The principal engineering difficulties attendant to the development of RCV's for practical military application are those associated with the communications system. Jamming, signatures and enemy interception of data are all potential problems. The most critical difficulty, however, is the transmission and display of the massive quantity of feedback information required for remote operation in the cross-country environment. Because of the complexity of that environment, the operator of an off-road RCV will almost certainly require a continuous, panoramic visual display, with resolution at least equivalent to that provided by commercial television. Research is needed to establish the precise nature of communication requirements for various potential RCV missions and the associated implications for system development.

In another concept, remote control, coupled by force and position feedback, appears attractive in the development of man amplifiers and walking machines. At present, these concepts are workable, but the complexity and costs make for impractical systems. An important area for development, therefore, is mechanisms and techniques which make feedback control systems practical for land vehicle application.

C. Driver Aids

The driver was identified as a neglected key element in operational mobility. To get more out of the driver, we must provide him with better training and improve his operating environment and his interfaces with the vehicle.

1. Driver Training

The differences in vehicle performance achieved by trained and untrained drivers are vast. Current Army training practices do not appear to be fully effective in training the driver to exploit the total performance potential of his vehicle under extreme conditions of use. Providing such training in a real vehicle under realistic field stress conditions is both expensive and dangerous. It is suggested that simulator

devices, similar to those currently in wide use for pilot training, could also be profitably employed for training off-road vehicle drivers. There is a well-developed related technology base deriving from the activities of workers in the highway safety field who have developed a variety of road simulators for both research and training purposes.

The major impediment to the development and practical use of off-road driving simulators appears to be the difficulty of providing realistic simulations of visual displays and other necessary driving cues at reasonable cost. Research appears needed to establish just what level of realism is necessary to make a simulation useful for training purposes.

Even with extensive use of simulators, complete training requires a certain degree of behind-the-wheel field experience. To make such experience most effective, it should be obtained under operating conditions which tax the vehicle to its limits. Research consideration must be given to the design of suitable training courses and associated programs of instruction.

2. Shock and Vibration Alleviation

The major driver environmental factors detrimental to mobility are those associated with shock and vibration. A number of recommendations were made for the alleviation of these factors.

- Use of an active suspension that senses the terrain ahead and displaces suspension elements in anticipation of oncoming irregularities. The sensor could be an on-board laser, sonar, etc., or a mechanical device in a lead unit, perhaps remotely controlled.
- Use of a suspension system which automatically varies its spring rates, damping rates and static attitude in response to vehicle load and terrain inputs. The inherent variable attitude feature would reduce the elevation requirements of a vehicle-mounted weapon.

- Use of crew isolation to reduce requirements for suspending the entire vehicle. This concept could be implemented in a small way with an improved (suspended) crew seat. The full concept envisions the crew to be concentrated in a separately suspended compartment. Suspension of this compartment would probably have to be active, and controls remote.

- Use of specially designed suits which would increase crew tolerance to shock and vibration. Conceptually, this suit could resemble a "G" suit such as used by airmen, or it could be a special harness or sling system.

3. Driving Cue Augmentation

Providing the driver with more and better information on the status of his vehicle in relation to the operational environment promises to improve his effectiveness materially. Systems that appear to have potential are:

- Television, mirrors or fiber optics to extend the driver's field of vision or to allow him to be placed at a more convenient or stable location. These systems could incorporate vision intensifiers for operation under reduced visibility.

- Navigation or guidance systems, either on-board (inertial) or remote (LORAN, etc.) to aid the driver and crew to operate in unfamiliar terrain. Such systems would lessen the need for detailed maps and movement control and would be especially valuable during night operations, in snow or heavy fog, or in terrain such as mountains, forests and deserts, where there are few recognizable features for guidance.

- Remote terrain sensing and analyzing systems to produce mobility maps to aid in route selection, mission operations and driver control. Such systems could be operated from aircraft or satellites.

- A system which detects the water content of a soil would be extremely useful, since,coupled with other terrain characteristics (vegetation, soil, type, etc.), this knowledge would give strong clues regarding soil strength. If day-to-day records of soil moisture condition were maintained, optimum times for operation through an area could be forecast.

- Tactile feedback to the driver of the traction conditions at the soil-vehicle interface. Knowing how much traction is available to each set of running gear would enable the driver to proportion torque application in an optimum manner.

4. Human Engineering

There are human engineering improvements that can enhance vehicle mobility by facilitating the mechanics of driving and by alleviating psychological stresses on the driver. Among the former are more utilization of power assists, more control automation, simplified control settings, greater adjustability of controls to match driver physique, and, perhaps, greater use of audio, tactile and/or odor signals to communicate appropriate information.

The importance of driver confidence is not as well recognized. It has been demonstrated that the driver of an M151 truck will go significantly faster cross-country if given the added sense of security provided by a roll bar. This experience suggests the desirability of such other features as:

- Easily released and discarded lap and shoulder safety belts.

- Rapid ejection systems for crews of combat vehicles.

- Simple, secure distress signal systems to inform friendly forces of immobilization, injury, loss of way and other factors such as enemy activity, etc.

5. Driving Task Sharing

Rational division of the driving function between two individuals would double the sensing, analysis and manipulation capabilities available to perform the difficult task of driving at high speed cross-country. By such dual control, one operator would directly set and keep the general course and route selection; while the second driver would concern himself solely with the terrain immediately in front of the vehicle. This scheme exists in rudimentary form during buttoned-up tank operations and in more sophisticated form with a horse and rider.

6. Convoy Control

The Army's logistic tail is long and complex. At one point or another, supplies are generally moved in convoys, the mobility of which is determined as much by convoy control limitations as by individual vehicle performance. Principal operational problems are in the maintenance of convoy integrity and reliable convoy navigation under the stress of maximizing convoy speed in the general confusion of the combat and near-combat environment. Operations at night and in other situations, in which effective visibility is severely reduced, compound the basic problem.

One broad approach to solving convoy problems is to reduce dependence on convoys, per se, through the reduction of forward area line items, full exploitation of combat loads (by trucks, containers), improved load control and identification, etc. Non-convoy distribution could be implemented by the development of doctrine and hardware to apply traffic management techniques and rapid transit technology in the field to control and direct individual vehicles. Networks of rapidly deployable automated traffic sensors and directors could be developed which (using suitable transponders) could guide individual trucks on optimum routes under field computer control.

Possibilitiᵔs to improve the timely throughput of goods and trooos using convoys range from relatively simple on-board devices, to help drivers maintain intervehicle spacings appropriate to convoy speeds and road conditions, through to the development of fully automated systems for convoy dispatch, navigation and operation which might also significantly reduce convoy manpower and even convoy vulnerability.

There has been little significant work connected with technologic possibilities to improve convoy effectiveness since the early 1960's when possibilities to hard-couple tactical trucks for convoy use were briefly addressed. The bulk of .he possibilities lie within the state-of-the-art of various technologies. The major technical problem is determination of credible effectiveness benefits against which to compare inevitable costs associated with various possible degrees of system sophisticated at each major echelon in the TOE distribution system.

D. Vehicle Form and Operational Concepts

The basic form of a vehicle dictates its mobility envelope. A number of unconventional vehicular shapes and forms were suggested. Some were totally new concepts; some were old concepts which warrant re-examination and further development; and some were hybrid combinations of existing forms.

1. Helicopter/Vehicle Teams

The newest element in combat mobility has been the marriage of ground troops with helicopter transport. After dismounting, however, these heliborne troops are only as mobile as old-fashioned foot soldiers. To realize the full potential of this new approach, these troops, once on the ground, must be provided with highly mobile combat and tactical support vehicles which can also be transported by helicopter. Then obstacles such as marshes, forest, rivers, mountains, or mine fields can be by-passed at 150 mph by air; then after landing, the troops would have the high mobility and fire power necessary to press on with the attack. Shock effect would be maximized and vulnerability of the helicopters reduced, since the helicopters would no longer have to land close to enemy fire zones. Exploitation of this new opportunity will require some basic

changes in the morphology of both our ground vehicles and our helicopters (see Figure 5). Some of the unconventional vehicle forms suggested below are responsive to these new demands.

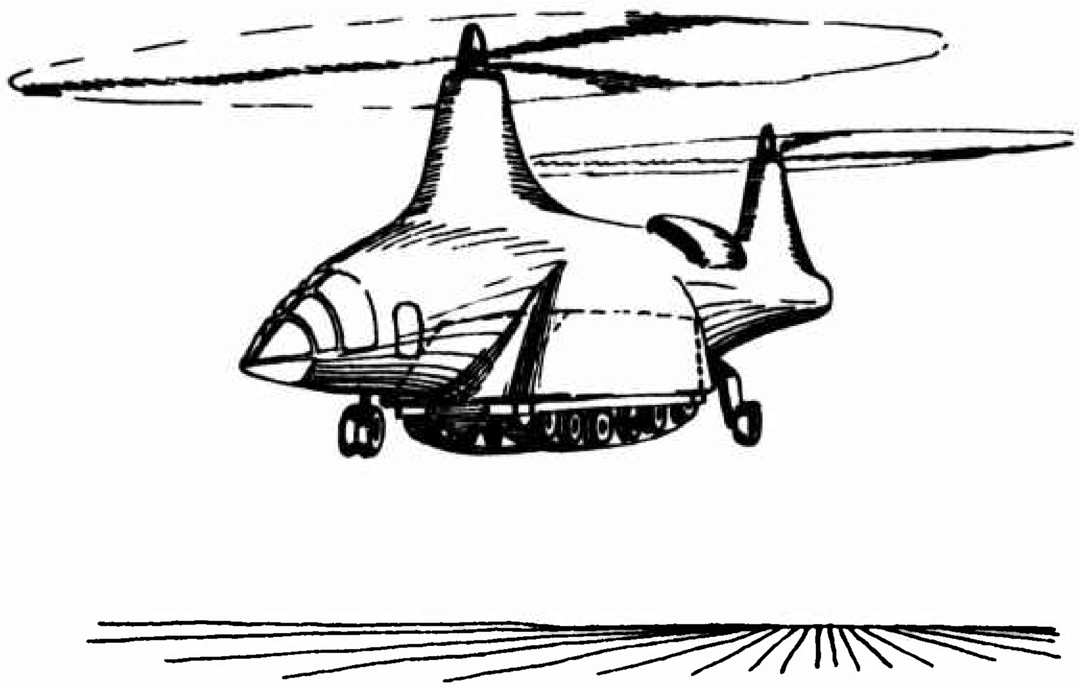

FIGURE 5. A MARRIAGE OF THE GROUND VEHICLE WITH THE HELICOPTER WILL PROVIDE THE SOLDIER MOBILITY AFTER PLACEMENT ON THE BATTLEFIELD.

2. Articulated Vehicles

With helicopter transportability as one goal, articulated vehicles can be designed for transport in sections, and almost instantataneously joined in the field (see Figure 6). This opens the possibility of moving vehicles up to tank size and capability right along with the first troops in an airborne assault. In addition, extensive mobility research and several recently completed vehicle development programs, have demonstrated the significant increases in cross-country mobility which result from vehicle articulation. Use of this feature should be widely applied to combat as well as to logistic vehicles, to achieve survivability through mobility/agility against modern weapons which cannot be defeated by armor protection.

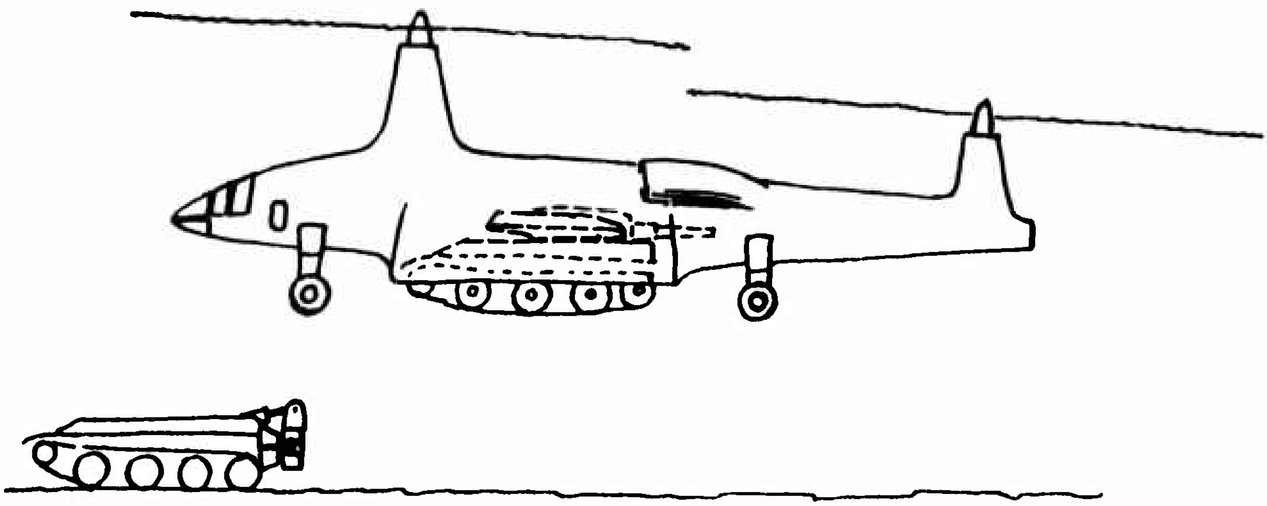

FIGURE 6. ARTICULATED VEHICLES HAVE THE ADVANTAGE OF BOTH INCREASED MOBILITY ON THE GROUND AND INCREASED TRANSPORTABILITY IN THE AIR.

a. Articulated Tank

The articulated tank(shown in Figure 7) could incorporate and optimize the following features. The vehicle would normally operate with its two elements coupled. It would be steered by yaw control of the articulation joint (which should materially increase track life by eliminating wear due to skid steering) and be provided with positive manual control of the pitch joint for superior obstacle negotiation. High wheel travel suspension and pitch stabilization of the rear unit through active control of the pitch joint (using the response of the front unit as basic inputs) would provide superior ride, especially in the rear unit, and a more stable gun platform for firing on the move. The articulation joint would include signal and fuel connections, releasable or couplable from the driver's station without crew exposure.

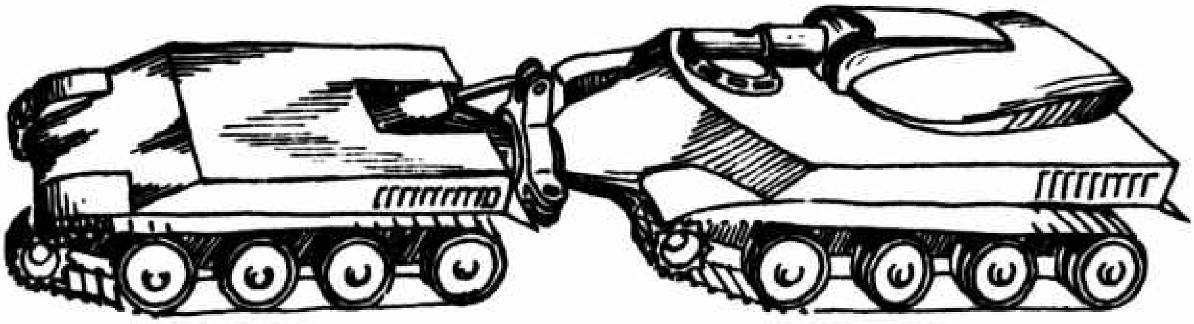

FIGURE 7. THE ARTICULATED TANK DESCRIBED IN THE TEXT OFFERS MANY OPERATIONAL ADVANTAGES.

The front element would be self-contained with its own powerplant, utilize simple skid steering when decoupled, and be remotely controllable by radio or hard wire from the rear element. It would carry the complete articulation joint, major remote control equipment, complete vehicle active pitch control system, spare fuel for the rear element, some armor, but no personnel. When decoupled, the front unit would act as a mobility aid, precursor vehicle for reconnaissance and mine detection, etc.

The rear unit would carry all personnel, weapons and fire-control equipment, remote controls for the front unit, and, in general, resemble a conventional skid-steered, tracked vehicle when decoupled from the front unit. It would also carry the primary powerplant and a nominal fuel supply and be fully operable (with reduced mobility) when run without the front unit.

The front unit, being less complex than the rear, would be considered semi-expendable. Thus, it could be utilized for mine clearing operations, reconnaissance (perhaps mounted with TV) and as a protective front shield from enemy fire. On the other hand, it would be an aid to the rear unit when negotiating obstacles and, in case of rear unit engine failure, would provide emergency get-home capability.

b. Articulated Wheeled Vehicles

A number of concepts for articulated wheeled vehicles were also suggested.

o A 12x12 - 4x4 convertible vehicle.

By utilizing the foldable-tire concept developed in the early 1960's by Fairchild for STOL aircraft, a vehicle could be provided with lightweight tires that would be folded when not needed (see Figure 8). On-road operation would be on four conventional tires;

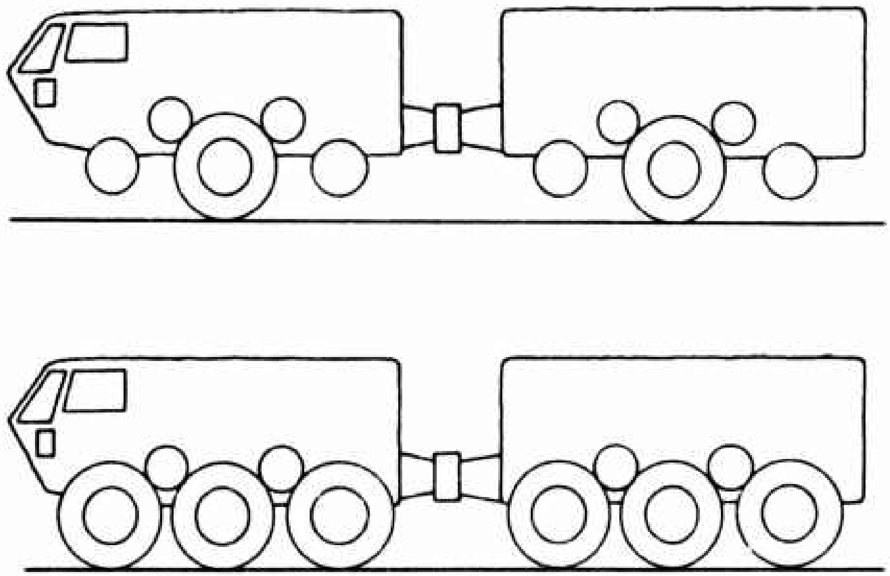

FIGURE 8. FOLDABLE WHEELS WOULD BE STORED WHEN NOT NEEDED (TOP) BUT INFLATED FOR SOFT TERRAIN (BOTTOM). FOLDABLE WHEELS WOULD BE POWERED BY SMALL IDLER WHEELS.

for off-road situations that require it, the additional tires would be inflated to provide additional flotation and traction. These extra tires would be powered, either by a conventional drive line or, more economically, by smaller idler tires which would provide friction drive between the regular drive wheels and the foldable tires. Frame-articulated steering would be one requisite to the practicability of this concept; another would be central inflation control of individual tires.

- Tactical trucks, specifically designed for operation in long hard-coupled trains.

  Tandem twinning of vehicles achieves the advantages of articulation in cross-country operation. Controls would be configured so that a driver could easily operate a train composed of any number of units for convoy work (see Figure 9).

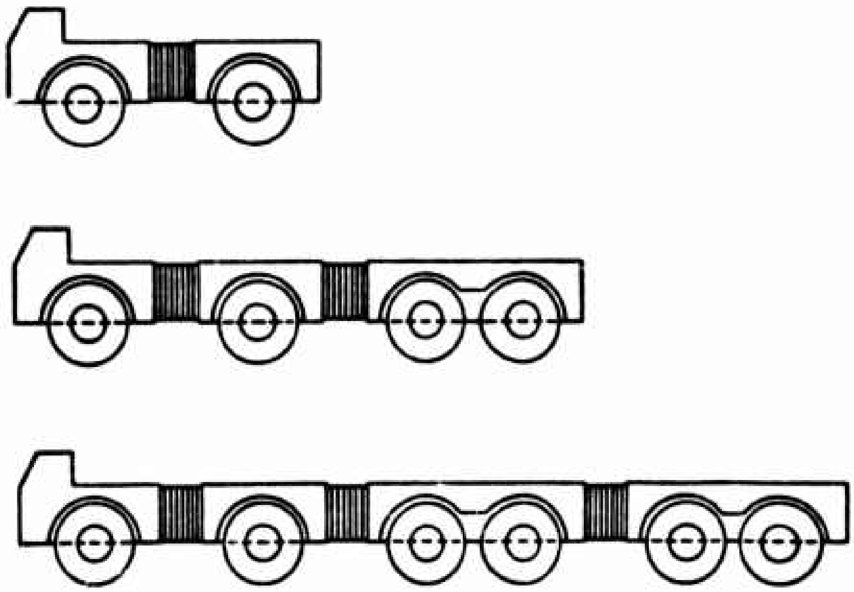

FIGURE 9. TRUCKS, SPECIFICALLY DESIGNED TO BE COUPLED TOGETHER TO FORM TRAINS. PRIME UNIT (TOP) COULD COUPLE TO OTHER PRIME UNITS OR TO CHEAPER SECONDARY UNITS TO FORM TRAINS (LOWER TWO SKETCHES).

- Motor cycle trains.

  The USDA Forest Service has developed a gyro-stabilized trail vehicle which runs on a single line of tires. Using this stabilization system, clever geometry and perhaps supplemental stabilization from small thrusters, a practical over-the-trail train under the control of one man might be developed.

3. Modular Design

A set of standardized modular subassemblies--power units, wheel suspension/drive units and cab/control units--which could easily be assembled into a vehicle tailored to the mission or could be used as replacement units for rapid repair of damaged vehicles, appears to be feasible and desirable (see Figure 10). The benefits of such bolt-on, plug-in components are:

- Commonality of parts over a wide range of vehicles.
- Reduced development and production lead time, both for new vehicles and for upgraded components.
- Reduced retrofit and rebuild time.
- Reduced training requirements, both for operators and mechanics.
- Increased production base, since smaller firms could make subassemblies.
- Reduced procurement costs due to higher production rates of most elements.
- Reduced support requirements (spare parts, forward maintenance).
- Closer match of power and wheels to vehicle load and terrain.
- Increased availability.

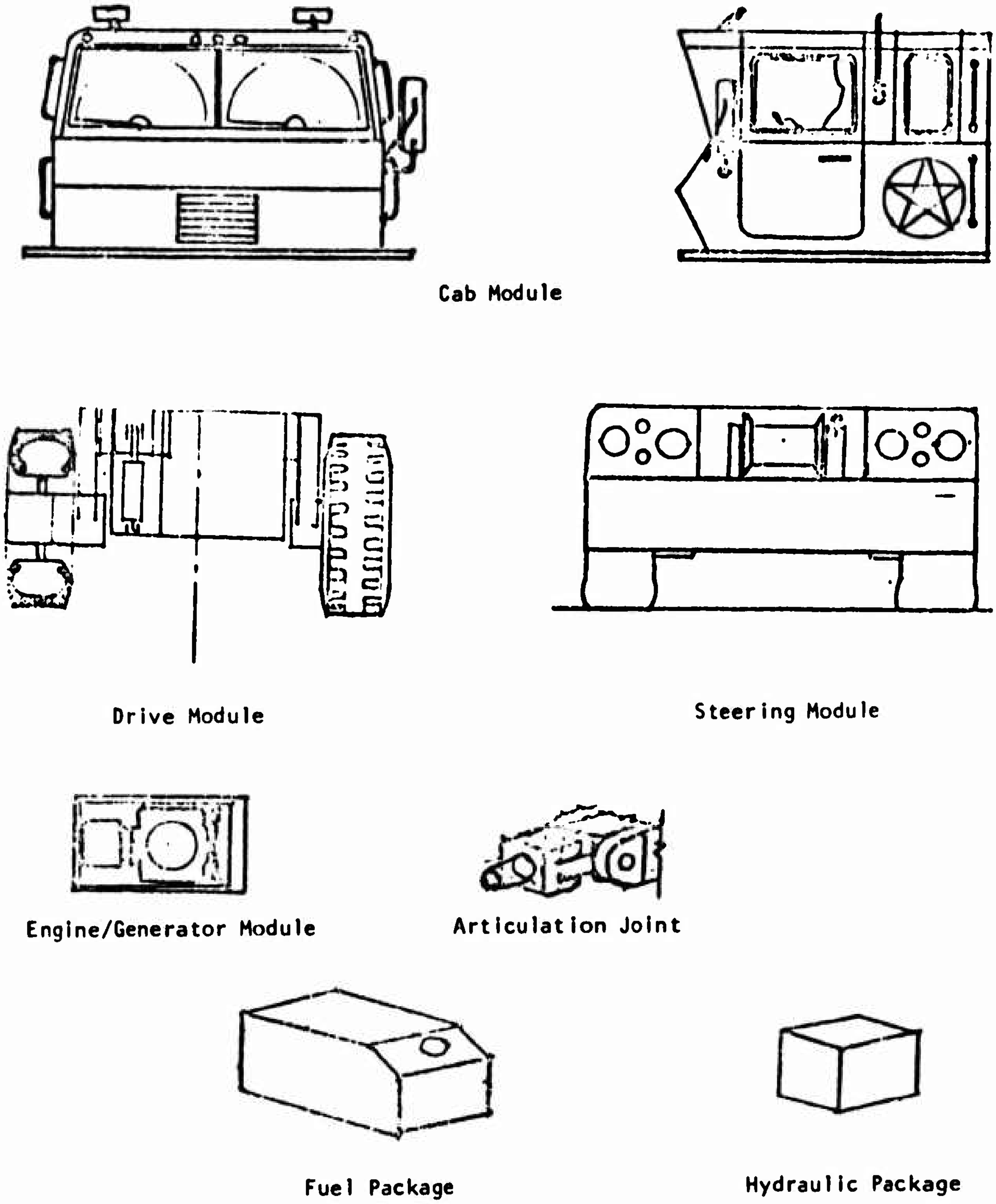

FIGURE 10. MODULAR COMPONENTS COULD EASILY BE ASSEMBLED TO A VARIETY OF FRAMES TO FORM MANY DIFFERENT VEHICLE CONFIGURATIONS.

Addition of a track/suspension/drive module would increase the flexibility of the modular design concept. Further flexibility could be achieved by designing a wheel/suspension/drive module specifically for expedient use in supplying power to the wheels of trailers in the tactical support fleet.

The development of modern electric drive systems of suitable capability or of more advanced mechanical in-wheel drive systems appears to be essential to achieve modular design. Such developments would make possible the elimination of the mechanical drive line, thus freeing overall vehicle design to attain simplified suspensions, more effective configurations, and highly durable, reliable, true all-wheel drive articulated wheeled vehicles which can be readily converted to tracked configurations.

Some specific technical questions which warrant immediate attention prerequisite to implementation of a modular-base fleet plan include the following:

- o A parametric fleet definition that includes determining the optimum size and number of modules, the associated levels of performance required, and the identification of elements now available and those which require new R&D efforts to achieve.
- o Special emphasis on defining new drive system requirements (electric, hydraulic, etc.), within and outside the current state-of-the-art in related technologies, which are implicit in the multiple module concept.
- o The space and weight limitations and penalties within the modular family.
- o The controls problem of multi-engines in the larger vehicles.
- o The feasibility of throwaway modules or, at minimum, readily replaceable modules to reduce the maintainability burden.

- The many problems of interfacing standard components and modules within the range of vehicle sizes considered.

- The cost effectiveness of the concept in its optimum configuration for the life of the fleet, reflecting upgrading of fielded modules and assurance of necessary RAM-D.

4. Air Cushion Concepts

The Air Cushion Vehicle (ACV) promises uniquely fast (50-120 mph) transportation over unimproved terrain including soft soil, swamps and combinations of land and water. This capability could give surprise, quick reaction and near all-weather operation, with minimum environmental damage. The promises of the ACV have not yet been fully realized, principally due to certain operational problems. Some of the problems and suggested solutions are:

- Slope climbing ability and control on slopes.

  Use a non-load bearing, limp chain or cables as tracks with simple, slow speed drive (patterned after systems used to propel some neutral-buoyancy ocean-bottom vehicles) for traction and control augmentation when required (see Figure 11). With this system, no other suspension components (wheels, springs, shocks, etc.) are necessary. The chain or cable is readily stowable and retractable when not in use. In use it would simply lie on the surface, conforming to the terrain under its own weight, and biting in when slip occurred.

- Lateral control.

  A serious problem limiting the versatility of air cushion vehicles is the lack of responsive and precise lateral control. Additionally, steady state slope negotiation above 10 degrees causes a serious propulsion system weight penalty. Positive lateral control

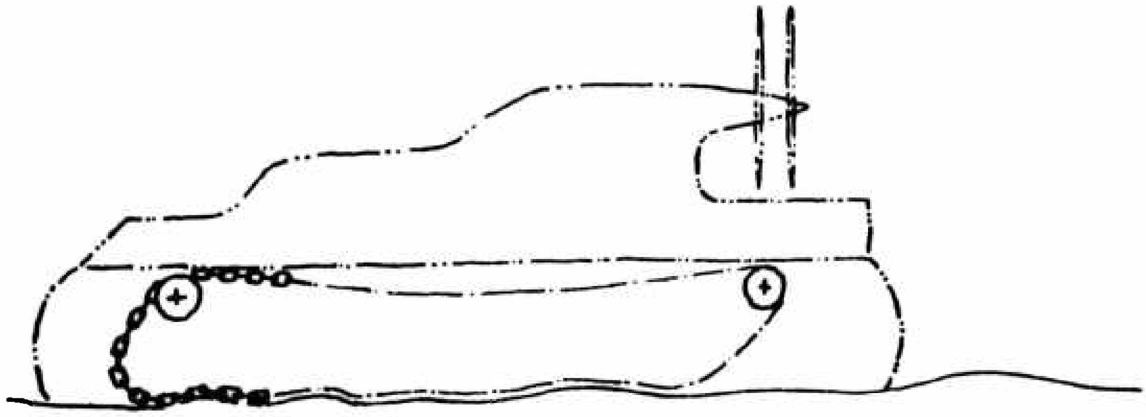

FIGURE 11. A POWERED, LIMP CHAIN, HANGING FROM AN AIR CUSHION VEHICLE COULD PROVIDE THE TRACTION NECESSARY TO GENERATE ADDITIONAL CONTROL AND SLOPE CLIMBING ABILITY.

would permit operation across slopes and, by climbing on the bias, permit negotiation of steeper slopes. A thin rudder-like vane or disk, one forward and one steerable aft and both spring loaded against the surface, could be utilized to provide needed high lateral resistance with minimal longitudinal drag (see Figure 12). Penetration into the surface would be caused by both a responsive suspension system and vibration of the contacting element; soil penetration would be inversely proportional to soil strength, hence only the penetration necessary to achieve the desired lateral forces would result.

5. Trailmaker (or Pioneer) Vehicle

Envisioned here is a high performance engineer vehicle specifically designed to support other vehicles with more conventional military functions or missions. The vehicle would be outfitted with on-board mobility aids not feasible in any other type of vehicle (pushers, compactors, winches, dozer blades, scoops, cutters, etc.) so that it could clear a path and improve

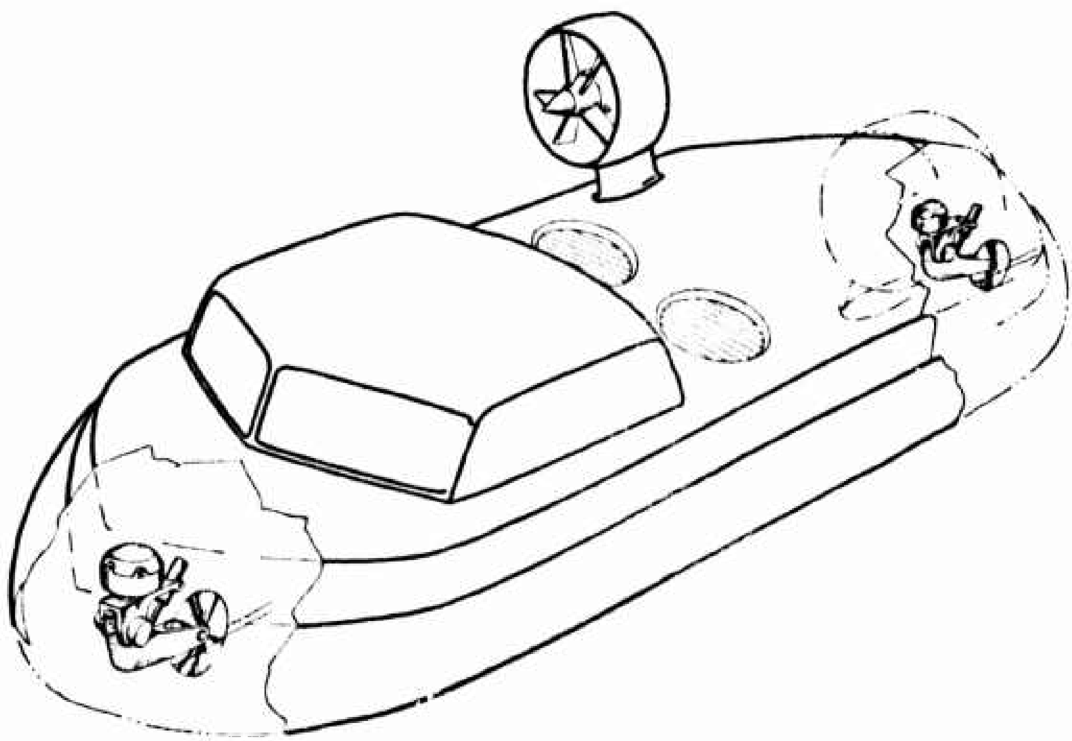

FIGURE 12. SPRING LOADED "PIZZA CUTTERS" WOULD PROVIDE POSITIVE LATERAL CONTROL FOR CROSS-SLOPE OPERATION.

the terrain for following vehicles. It would clear out vegetation, drain or fill in mud holes, reduce the steepness of banks, provide ramps over obstacles, etc. The vehicle, in itself, would be highly mobile so as to be able to operate effectively in the difficult areas in need of trafficability improvement. It would be ideal if this vehicle could clear a trail in one pass, by removing obstacles, banks, vegetation, etc. (much as a snow plow) and, at the same time, improving trafficability by compacting the soil. For operations during combat assault under fire, it could be remote controlled to clear paths over which troop-occupied vehicles could quickly move.

6. Advanced Airoll Vehicle

Development has recently been completed on the Marine Corps XM759 Marginal Terrain Vehicle which is based on the Airoll concept. That program proved that the Airoll system provided true, all-terrain mobility. Development of an advanced airoll vehicle system, perhaps articulated,

utilizing a high performance power train, lightweight cable drive, and lightweight non-vulnerable wheel/tire system offers the capability of significantly improving mobility, water performance, durability and reliability, reducing weight, and fielding a logistic or counter-insurgency combat vehicle capable of readily traversing the most extreme adverse terrain areas.

7. Advanced Screw Concepts

The ability of the Marsh Screw to operate freely in marshes and water prompted suggestions to improve its performance in other environments. The most promising approach would be to divide each rotor in two. Yawing the four resulting screws would provide a crabbing capability or, if yawed 90°, would provide wheel-like propulsion for operation on firm soils or roads (see Figure 13).

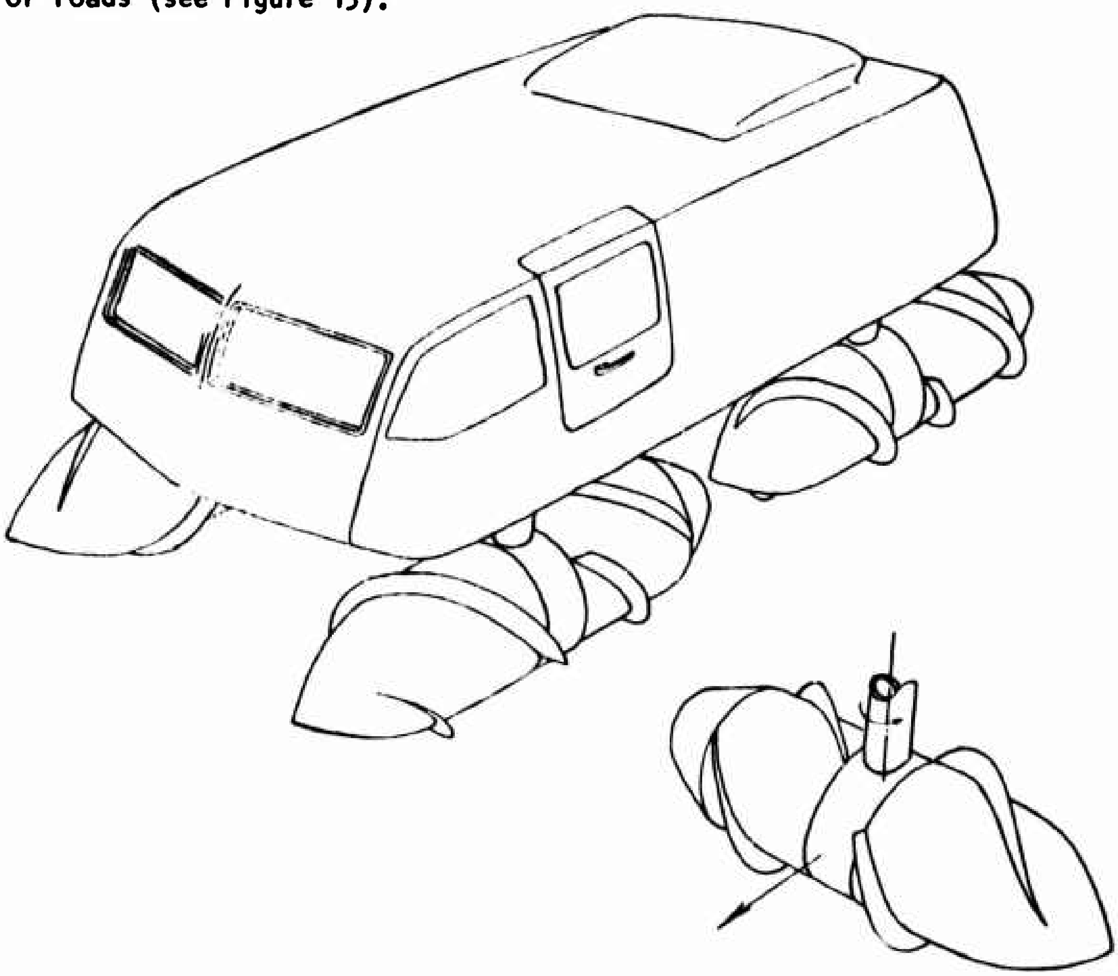

FIGURE 13. DIVIDING THE ROTORS IN TWO AND ALLOWING THEM TO STEER WOULD PROVIDE CRABBING ABILITY AND IMPROVED OPERATION ON FIRM SURFACES.

8. Urban Combat Vehicles

In general, we are ill-prepared for vehicle exploitation in combat operations in an urban environment. We should therefore attempt to develop vehicles which will operate freely in the congestion and rubble that would be expected in cities under combat conditions.

- Sewer Vehicle.

  Great use could be made of the city sewer system by a vehicle which would enter through a manhole, negotiate the sewer environment, and exit through another manhole. Such a small vehicle could also be used in cross-country environment to negotiate dense, closely-spaced obstacles (rocks, trees) and as a small amphibian.

- In-building Vehicle.

  A vehicle which could enter a building, climb stairs and knock down walls when necessary would provide necessary mobility and fire power both inside and outside buildings.

- Grabber.

  The Grabber would employ a remote-controlled hook or a man-amplified servo-mechanism to grab and propel itself. In the urban environment, it could climb up the outside of buildings; in the forest, it could grab trees or rocks. The arms could be used alone to swing, monkey style, from one "hand-hold" to another or, in conjunction with conventional suspensions, to yield assistance when appropriate. A simple variation of the Grabber would be a mechanical foot to push, lift, or pull a vehicle out of immobilizing situations.

9. Hybrid Vehicles

A number of propulsion schemes were considered for mating with conventional wheel or track systems. Initially, the following were suggested:

- o Air cushion
- o Helicopter rotors
- o Walking devices
- o Mud pumps
- o Archimedean screws (marsh screw)
- o Jumping capability

Subsequently, it was considered that the jumping vehicle and helicopter approaches were perhaps premature. Walking mechanisms were considered marginal at this time, as was the application of mud pump capable of propelling a vehicle stuck in the mud. The marsh screw and air cushion principles were considered to have the greatest potential (see Figure 14).

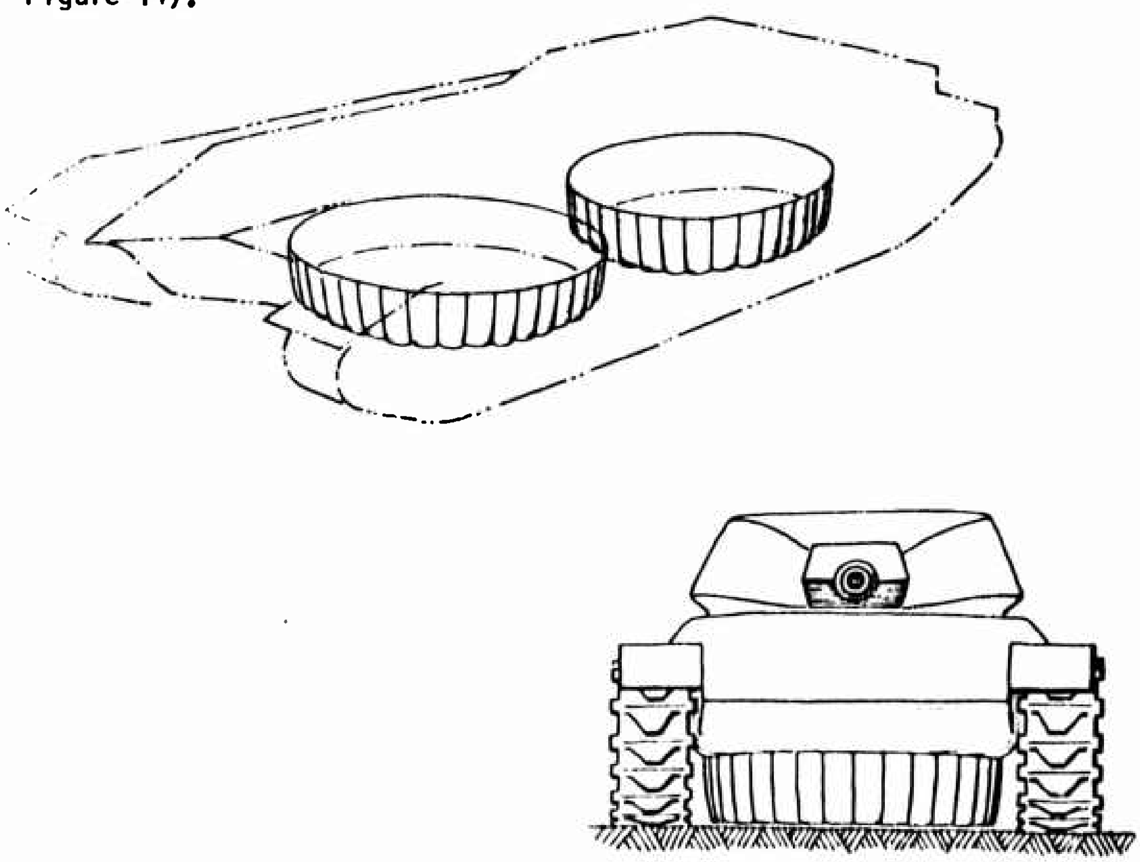

FIGURE 14. AMONG THE HYBRID VEHICLES CONSIDERED WAS THAT OF MARRYING THE TRACK WITH AN AIR CUSHION TO NEGOTIATE SOFTER TERRAIN.

Major stumbling blocks in developing a hybrid air cushion/ wheeled or tracked vehicle are the cost, weight and complexity of providing two separate, independent propulsion and suspension systems. On the other hand, it is feasible to construct inexpensive air cushion elements without propulsion systems, to be utilized as barges which permit supplies to be towed by cables or by a highly mobile vehicle over short stretches of impassable terrain. These elements could be linked together to provide auxiliary support to conventional vehicles or to form a bridge over which conventional vehicles may pass. Since they will not have to operate very far independently or to provide their own propulsion system, they could be made quite simple, light and relatively inexpensive.

10. Wheel/Track Convertibles

There is a continuing need for logistic mobility in special tactical and physical environments which is significantly greater than is provided by high mobility tactical trucks in the fleet. While operationally critical, the number of vehicles required is relatively small and the desirable variants are numerous. A potentially economical approach to this problem is to design our tactical high mobility trucks so that, by the field addition of suitable, integrated kits, some or all of the trucks may be readily converted to viable tracked vehicles to fulfill low density, extra-high mobility vehicle requirements. The basic concept would be to employ the track conversion kits on a preplanned basis--according to geographic location, season, large scale mission projections, etc. -- rather than on an ad hoc basis in response to rapidly changing tactical situations; although the latter operational possibility would not be excluded. Such operational doctrine, plus current air lift capabilities, should make it possible to avoid the "police syndrome" generally associated with kits; i.e., that they are never there when you need them.

It is essential that the design approach minimize compromises to cost and effectiveness of the host wheeled vehicles. It is equally important that conversion to tracked operation through the addition of the kit produce a substantial mobility increment.

Two approaches should be examined. The more desirable from a parochial viewpoint is the design of the high mobility fleet for hybridization from the ground up. In this approach, the scope of the kit modification can be minimized. Chassis articulation appears essential to maximize the mobility increment. The alternative is to examine what might be done by minor redesign of more standard truck configurations which might be available from regular automotive production lines. Kit requirements might have to be expanded from simply a set of tracks to include added undriven axles, perhaps a chain drive sprocket, front wheel skis, etc.

Detailed problems are foreseen in obtaining positive drive between tires and the track in critical conditions (which may require attention to a special tire), track throwing, poor ground pressure distribution (an important consideration, especially in snow) and potential tire wear and damage. The philosophy of track design needs examination, and tradeoffs among track life, weight, costs, and performance must be studied.

E. Propulsion Concepts

1. Direct Use of Energy at the Soil-Vehicle Interface

A dramatic savings in weight, complexity and efficiency could be achieved if combustion energy would be used directly at or near the soil-vehicle interface to obtain forward thrust. Such a system would propel a vehicle directly from the combustion gases without passing the energy through an engine-transmission-drive line system.

The "red-sod" system employs direct combustion of a fuel-air mixture to excavate soil. A take-off on this idea would be the use of open, vehicle-mounted cylinders which react fuel combustion gases directly on the soil to produce thrust and control forces.

There is a Czeck invention which utilizes compressed air to propel a tire by sequential inflation and deflation of circumferentially segmented chambers (see Figure 15). The direct use of combustion gases, rather than compressed air, would make this concept significantly more attractive. Proper timing of the intake and exhaust could be utilized to provide spring and damping action in addition to propulsion.

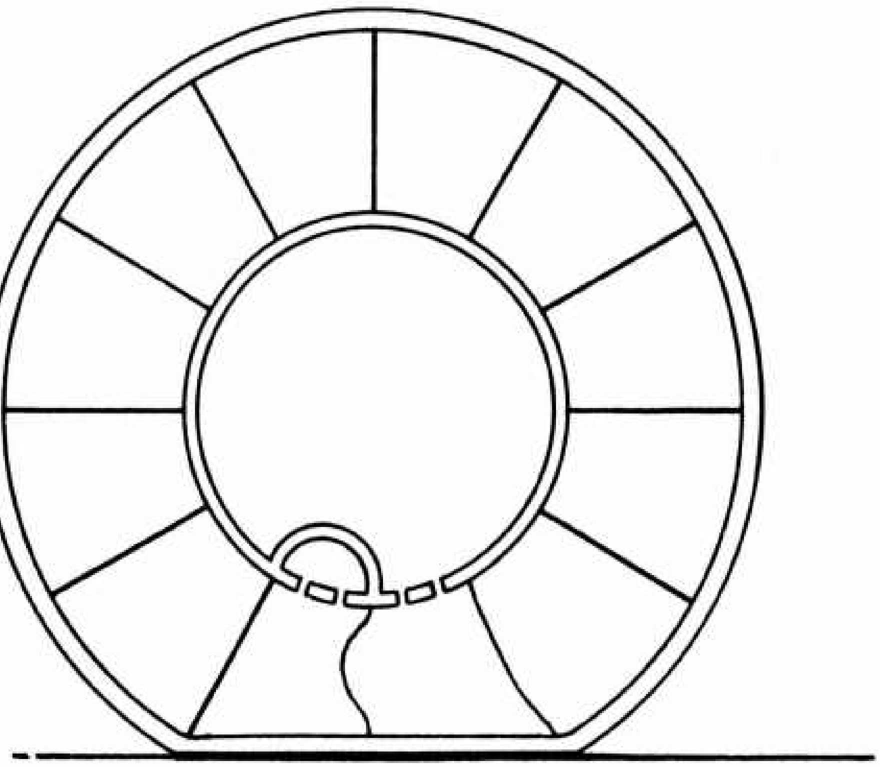

FIGURE 15. DIRECT USE OF THE COMBUSTION GASES TO INFLATE AND DEFLATE CIRCUMFERENTIALLY SEGMENTED TIRE CHAMBERS COULD ELIMINATE THE ENGINE-TRANSMISSION-DRIVE LINE SYSTEM

At this point in time, the above are no more than rather foggy ideas. What is needed now is a true invention; i.e., a reasonable outline of a mechanical realization of the concept. And even if feasibility can be demonstrated on paper, a substantial engineering effort will clearly be required to develop the concept in metal.

Foreseeable difficulties include fuel efficiency, materials, controls, space and weight problems, complexity, signatures and potential speed limits. Dynamics problems at the soil interface, dynamic feedback to the vehicle, and maximum thrust limitations (especially with the in-tire combustion idea) are fundamental problem areas requiring early clarification.

Additional possible realizations of the concept were also identified:

- o Use of reaction thrusters exploiting (in some unspecified way) ground effects substantially to increase static thrust.
- o Development of a waveform contact area deriving directly from in-unit combustion.
- o Use of the in-tire combustion idea in a bag-type track.

2. Linear Induction Motor Applications

Current research developments in linear induction motors offer possibilities of simplifying track drive systems and of separating the propulsion task from the suspension task.

- o A LIM mounted in the vehicle could propel a track (Figure 16) or wheel (Figure 17) without the drive-line and gear systems required for conventional electrical drive systems.
- o For a tracked vehicle, a LIM system would reduce the losses inherent in sprocket drive systems.
- o Magnetic systems or air bearings could be utilized to provide suspension support.

Successful implementation of any of these ideas requires development of low cost, durable and efficient linear induction motors which, in turn, require development of low cost super-conducting materials, preferably operating at room temperature. There are inherent problems associated with generating inefficiencies, electro-magnetic radiation (signatures and safety), maintenance, vulverability and durability due to exposure to elements.

Linear induction motors may or may not be the best approach to eliminate the severe restrictions imposed by mechanical drive systems. To account for this possibility, the following list of general development goals for <u>any</u> electric drive for use in a mobility system application was formulated:

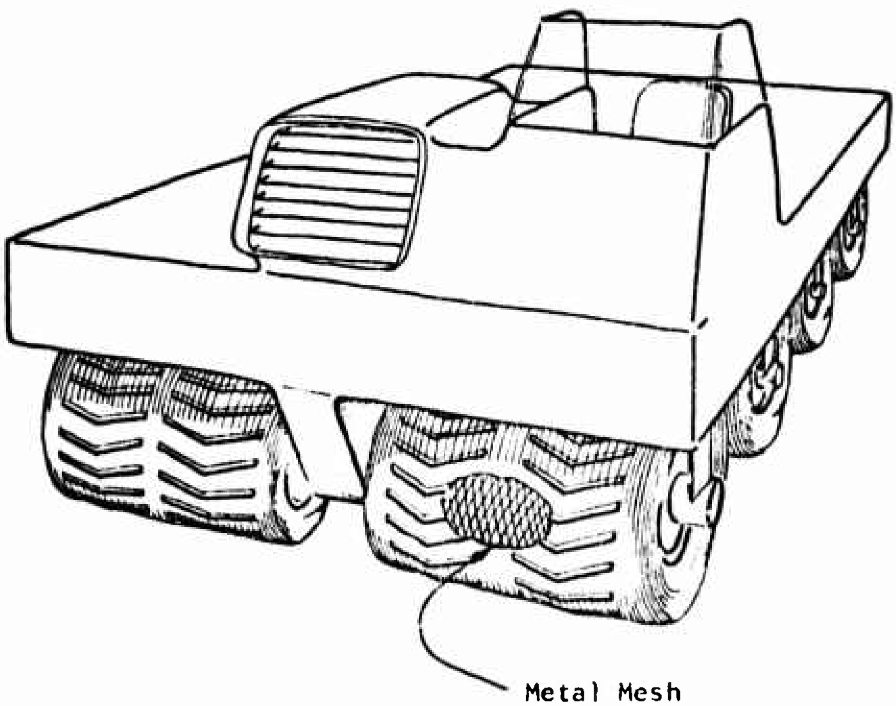

FIGURE 16. A LINEAR INDUCTION MOTOR COULD DRIVE A METAL IMPREGNATED BAND TRACK WITHOUT THE DRIVE-LINE AND GEAR SYSTEMS REQUIRED OF CONVENTIONAL TRACKS.

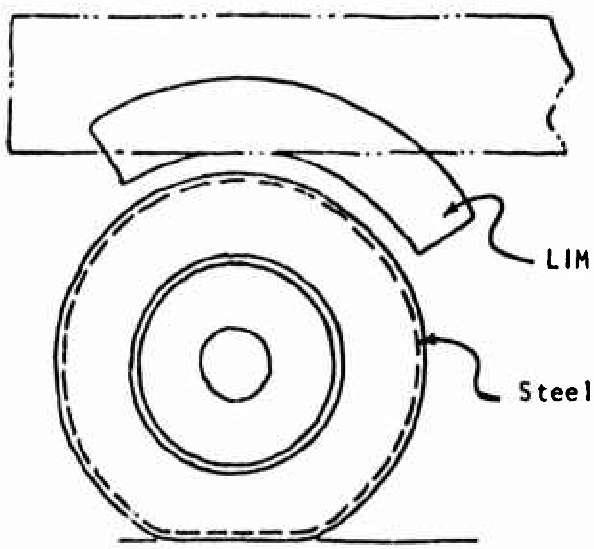

FIGURE 17. IN A MANNER SIMILAR TO THAT SHOWN IN FIGURE 16, A LINEAR INDUCTION MOTOR COULD DRIVE A STEEL-BELTED TIRE.

- Greater transmission efficiency (in the order of 80 to 90% for the total system) over most of its operating range.
- Lower weight and cube motors (at outside, should not weigh more than an equivalent mechanical drive system).
- Production cost comparable to mechanical drive system.
- No final reduction drive torque multiplier.
- Simple, low cost control systems.

3. Alternate Fuels

Our dependence on hydro-carbon fuels makes our field forces extremely vulnerable in the case of a critical fuel shortage caused either by the growing world-wide depletion of fossil fuels or, on a smaller scale, by the interruption of our normal supply sources. Four related solution approaches were identified:

- More efficient utilization of combustion waste products (heat, gas flow) by utilizing them to power auxiliary systems (heaters, electrical generators, turbo-chargers, etc.).
- Systems to manufacture, store and transport large quantities of synthetic or substitute fuels (hydrogen, methane, propane, etc.).
- New propulsion systems or adaptations of existing systems which can operate well on substitute fuels.
- Propulsion systems which can operate on indigenous fuels (coal, wood, waste products, etc.). Steam, Sterling, Brayton and Minto engines offer possibilities in this area.

4. Microwave Power Transmission

Recent studies indicate that energy transmission by microwaves can have relatively high efficiency. Thus, microwave energy, generated at mobile rear area generators could be used to power suitably designed vehicles and weapon systems. The power stations would be nuclear or burn indigenous fuels. Potential advantages are:

- o Less use of scarce petroleum fuels.
- o Lighter, more air-transportable vehicles.
- o Lower individual vehicle detection signatures.
- o Suitable to modular electric drive concepts.

5. Hybrid Power Concepts

The incorporation of dual power systems in combat vehicles holds the promise of utilizing inexpensive, efficient fuels at times of low power requirements, yet having the capability of generating high power at the relatively fewer times when such levels are required. Energy for peak loads could come from the use of special fuels or explosives or could be generated during times of low power requirements and stored for later, short-term use.

F. Flotation and Traction Aids

A number of devices were suggested that could be utilized to enhance conventional vehicles by providing augmented flotation or traction. The more promising concepts are listed below.

1. Limited Slip Differentials

The continuous and properly proportioned distribution of driving torque to all wheels under varying tractive and wheel loading conditions is a prime requisite for improved off-road mobility on multi-axle wheeled vehicles. To achieve this goal, limited slip differentials with 100% torque bias capability are essential. Present locking differentials are complex, costly and unreliable. A program to develop a simple, workable system is urgently needed.

2. Band-Type Tracks

Band tracks offer reductions in noise, vibration and power consumption. While such tracks exist for lighter vehicles, there are none presently for vehicles in the 10,000 to 120,000 pound weight range. A series of narrow, lower capacity bands, mounted in parallel would be a first approach to increasing band track capabilities.

3. Flexible Track Shoes

By making track shoes flexible, they could conform to imposed stresses (see Figure 18). Such design would make tracks lighter and there would be a more uniform load distribution to the terrain, thus improving trac.ion, flotation and wear.

4. Adjustable Track Shoes

By means of pneumatic pressure, explosives or chemicals, track shoes could be made to:

- o Vary width to reduce ground pressure when necessary.
- o Vary surface characteristics to decrease slipperiness.
- o Deploy spikes for ice or hard, slippery surfaces.
- o Vary flexibility to conform better to the terrain.

5. Emergency Belly Wheels

Wheels, stowed in the vehicle body (perhaps deflated and collapsed) could be deployed when the vehicle bogs down. Wheels may be bags (like a rolligon) and may or may not be powered. Inflation beyond normal could be used to jack vehicles off obstacles. The newly-developed pillow drive might find application here.

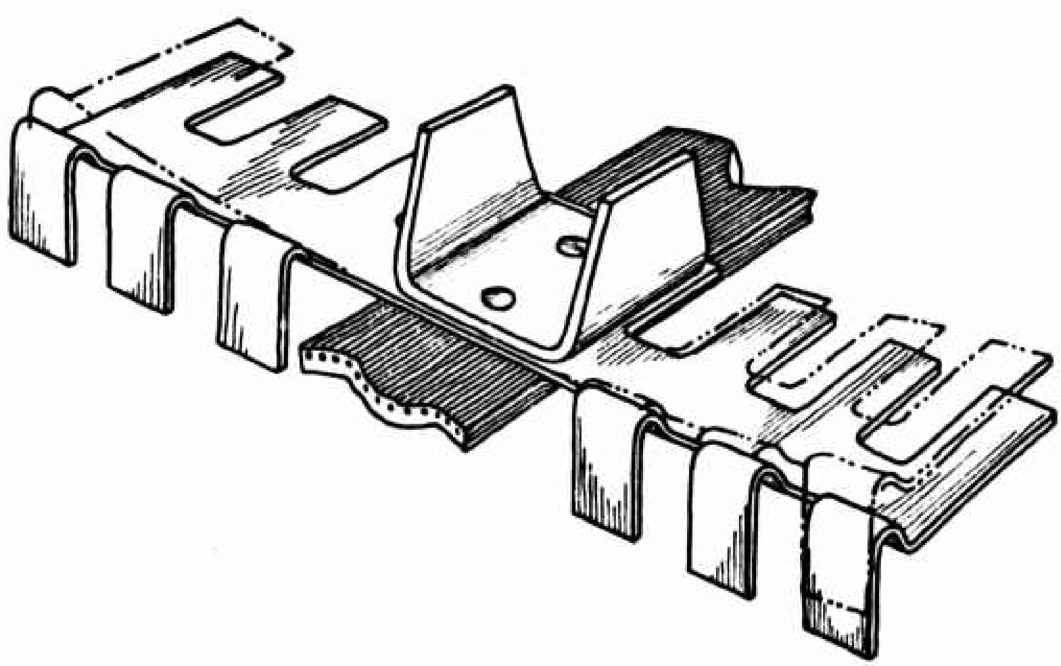

FIGURE 18. TRACK SHOES, WHICH ARE DESIGNED ... LD TO IMPOSED STRESSES, RATHER THAN TO RESIST THEM, COULD MATERIALLY LIGHTEN TRACK DESIGN.

6. Water Jet

An explosive or stored pneumatic pressure could be used to power a short-term water jet to provide auxiliary thrust for brief periods while overcoming obstacles (see Figure 19). Such a system would be especially useful and practical during river exiting.

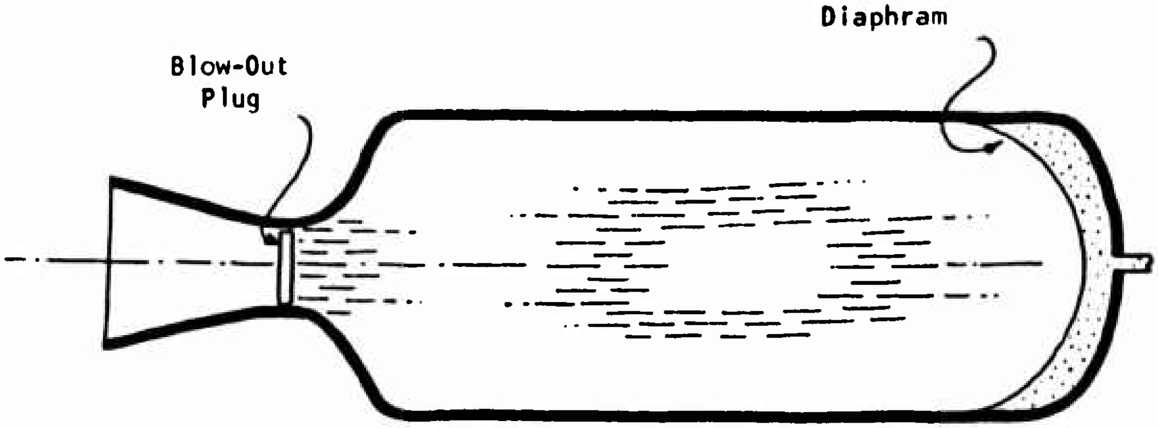

FIGURE 19. A WATER JET, POWERED BY COMPRESSED AIR OR EXHAUST GASES, COULD PROVIDE SHORT-TERM AUXILIARY THRUST WHILE OVERCOMING OBSTACLES.

7. Special Tires

Many of the difficulties encountered with wheel/track systems, and with tracks mounted on pneumatic tires, would be avoided by the development of tires especially shaped to mate with tracks.

Likewise, tires especially designed for friction drive systems would make such drive systems more practical and simplify the driving of multi-axle configurations.

For operations on slippery surfaces, traction would be aided if tires had cleats which automatically deploy to aid traction.

Road wheels which extended through and beyond the track would eliminate the need for rubber track pads to protect the road, reduce vibration and extend track life.

G. External Mobility Aids

In addition to integral traction and flotation aids, a number of external aids were suggested to enhance mobility.

1. Deployable Pushing or Pulling Devices

The most frequently suggested external mobility aid was a self-deployable and self-anchoring pushing or pulling device. Such a device would incorporate some element that could be launched from the vehicle, anchored or attached to the soil, a rock, or a tree, and be used to aid the vehicle over an obstacle or through an impassable area. Most promising concepts are:

- An improved capstan-type system, with the diameter of the capstan larger than that of the drive sprocket so that when the track begins to grab, the tension on the capstan is not released (see Figure 20).

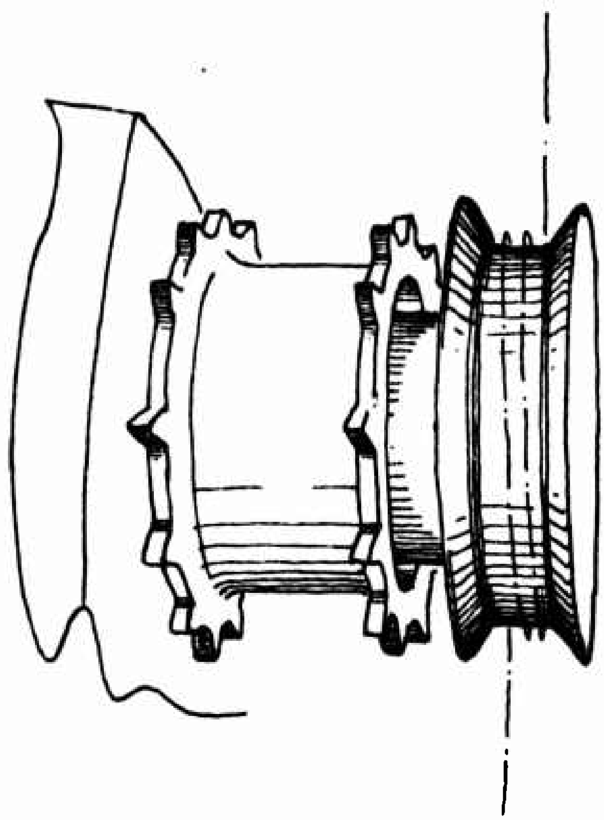

FIGURE 20. TO MAINTAIN ROPE CONTACT WITH THE CAPSTAN WHEN THE TRACKS BEGIN TO GRAB, THE CAPSTAN DIAMETER MUST BE GREATER THAN THE PITCH DIAMETER OF THE DRIVE SPROCKET.

- o A cybernetic gripper that uses man-amplified servomechanisms to reel in an anchored cable.
- o A rapidly emplaced system like a ski tow, which could be used to pull vehicles up embankments or through soft terrain.
- o A system which synchronizes winch speed and track or wheel speed to enable both systems to aid propulsion without fouling.
- o An anchor launching system which utilizes a fuel-air mixture or exhaust gases as a propellent.
- o A simple, exhaust-powered ram, capable of pushing against the soil, rocks, trees or other protuberances.

2. Floating Aids

Attention was called to the recent Dutch recreational invention that consists of an extremely large, plastic, transparent bag in which a person can stand and walk the bag over a body of water. Such a device could be used by foot soldiers or a walking machine (see Figure 21). Properly adapted, it might also be utilized as an aid to vehicles in crossing soft soils or water. For soils, the bag could be replaced by a steel mesh cylinder which would spread out the load and provide support between gaps.

For a towed vehicle, a plastic bag or perhaps a spray-on film could be used to encapsulate it, making it buoyant, so that it could be floated across water obstacles. Separate bags, inflated by exhaust gases, could also be attached to the vehicle to provide auxiliary flotation.

On-board stored or generated hydrogen or hot exhaust gases could be used to inflate large, lightweight plastic balloons to reduce effective weight as an aid in negotiating some soft soils, obstacles or rivers.

FIGURE 21. A PLASTIC BUBBLE WOULD ALLOW A FOOT SOLDIER TO "WALK ON WATER". SUCH A DEVICE IS PRESENTLY IN USE FOR RECREATIONAL PURPOSES.

3. Terrain Modification Aids

Vehicle-mounted terrain modification aids offer great promise, since they need be mounted on only a few vehicles to improve the mobility of many.

- A vehicle-mounted back-hoe, front end loader, or similar device, could be used to demolish steep banks, remove obstacles, fill in gaps, etc. (see Figure 22).
- A high-pressure hose could be used at river banks to wash away steep banks and make them gentle enough for vehicles to mount (see Figure 23).

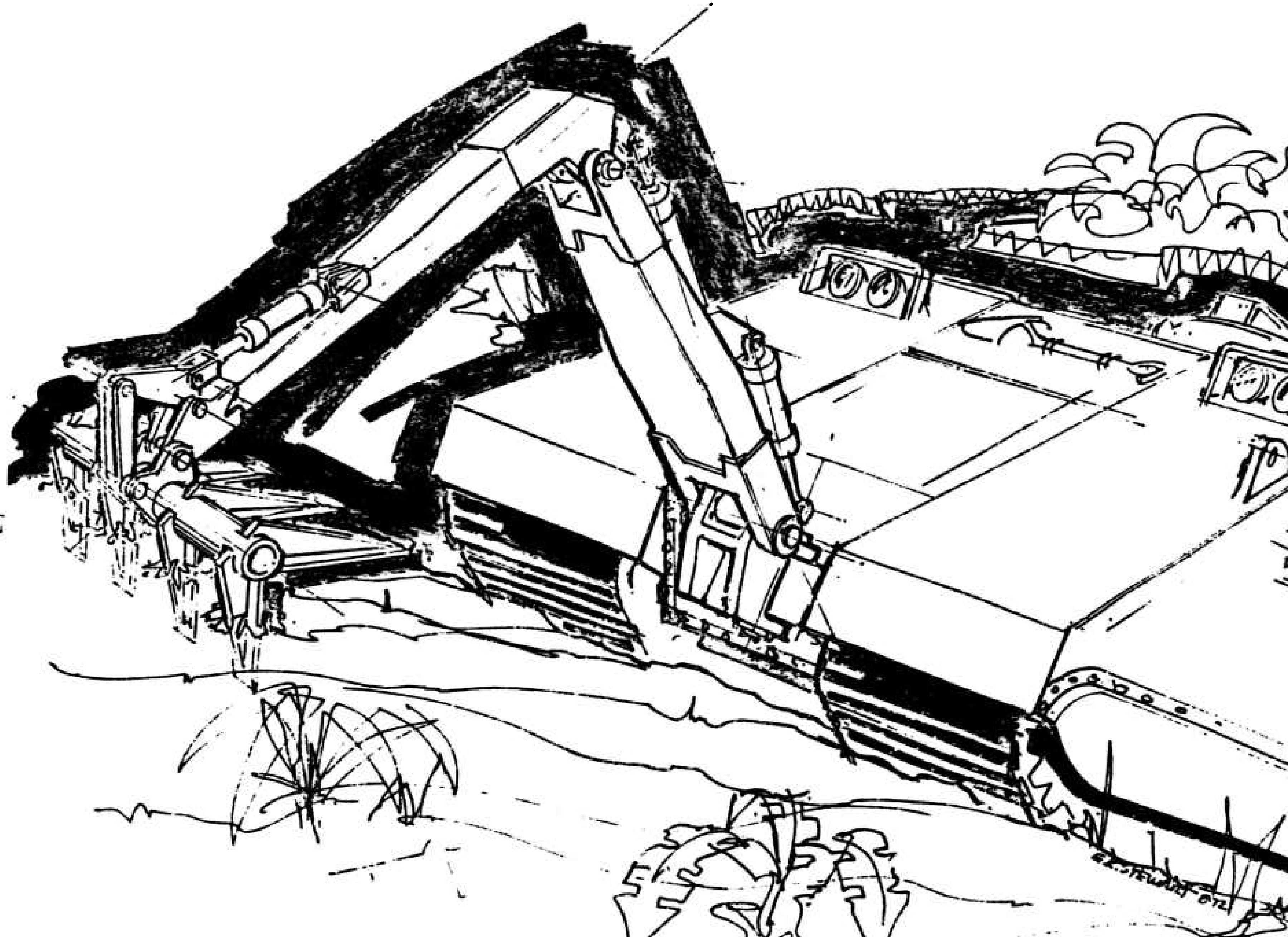

FIGURE 22. VEHICLE-MOUNTED EXCAVATION DEVICES, SUCH AS A BACK-HOE OR FRONT-END LOADER, COULD BE USED TO REDUCE OBSTACLES AS WELL AS AID MOBILITY BY PROVIDING ADDITIONAL PUSHING FORCES.

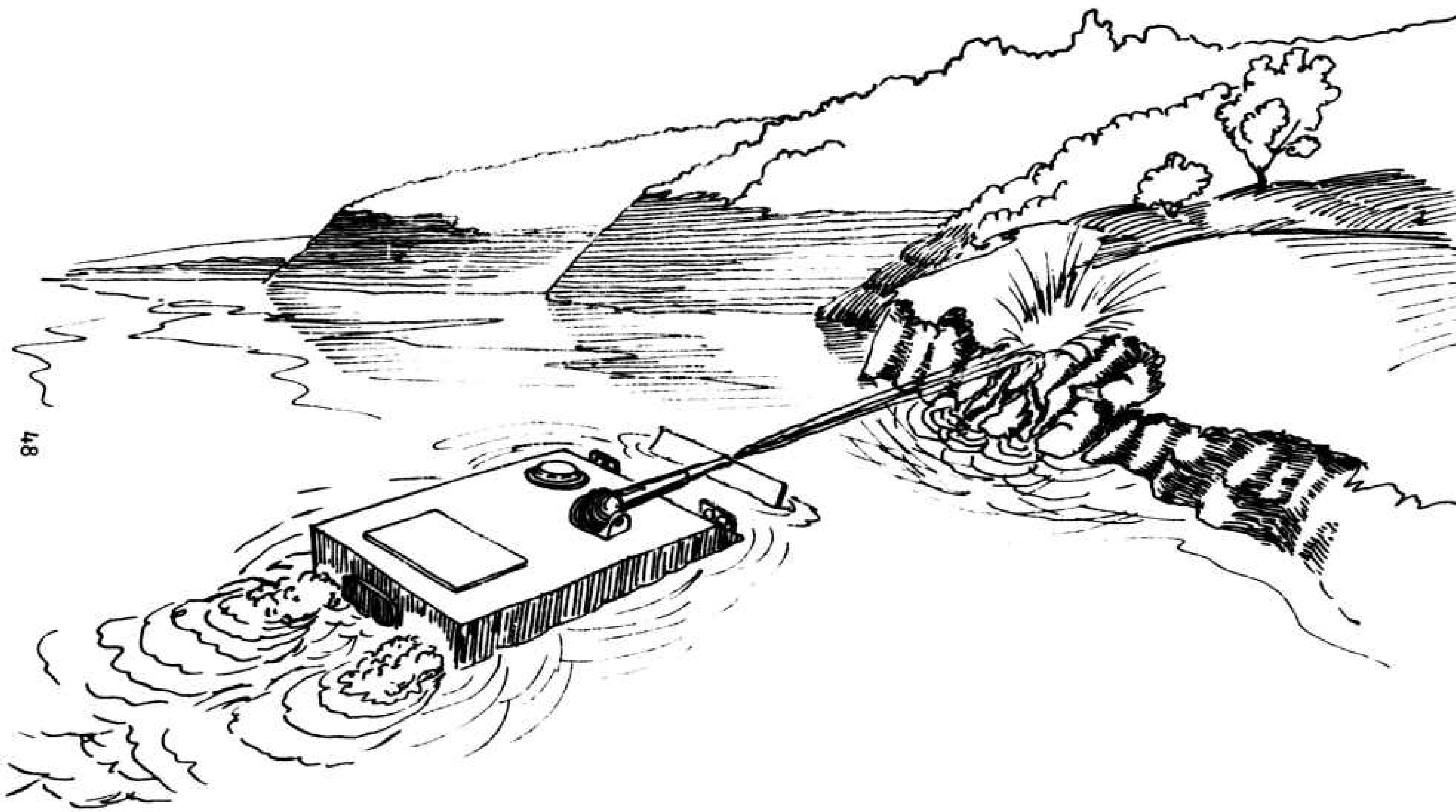

FIGURE 23. A HIGH-PRESSURE HOSE, MOUNTED ON AN AMPHIBIAN, COULD BE USED TO REDUCE RIVER BANKS TO A MANAGEABLE SLOPE.

- Vehicle-mounted chain saws could be used to remove vegetation which obstructs mobility or to emplace vegetation which would aid mobility.

- Bangalore-type torpedoes could clear vegetation, rocks or other obstacles could be used to demolish banks.

- Quick-setting foams or epoxies could be used to strengthen soil, reduce the slipperiness of banks or fill in gaps (water courses, ditches, bomb craters). The foam could either combine with the water to form firmer terrain by extracting moisture from the soil or it could overlie the soil, thereby effectively reducing ground pressure; also small areas could be hardened to provide anchoring points for winches or pushers.

- Accelerated hardening of disaggregated snow, as developed for Arctic landing fields, could be applied to off-road vehicle operations in snow.

- Rolls of fencing could be dropped in trenches or placed alongside steep banks (see Figure 24). During World War I, British tanks carried such devices (called fascines). Today we could use lightweight inflatable or foaming materials.

- Adjustable ramps, set at the proper angles, could provide smooth launch and recovery of vehicles crossing gaps, banks or other obstacles. Such systems are now commonly used by "car rodeos." For military applications, the systems would require a calculating facility to establish the proper launch angle and velocity and the matching recapture contour (see Figure 25).

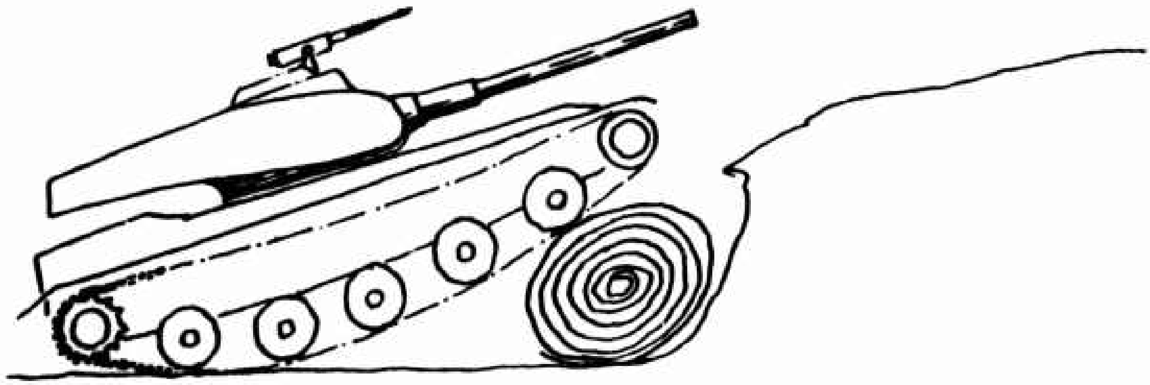

FIGURE 24. IN WORLD WAR I, TANKS CARRIED BUNDLES OF STICKS OR FENCING TO HELP BRIDGE TRENCHES. SIMILAR DEVICES COULD STILL BE UTILIZED.

H. Software Ideas

Although the primary objective of the workshop was the generation of hardware ideas, all of the working groups were motivated to make recommendations for improving the associated software technology base. It was, in fact, generally agreed that the single most pressing need confronting military engineers and decision-makers concerned with the design, development and deployment of land vehicles was a validated, objective methodology for the evaluation of vehicle performance, effectiveness and costs. It was recognized that the fulfillment of this need would require the expenditure of funds and considerable additional effort in research and development.

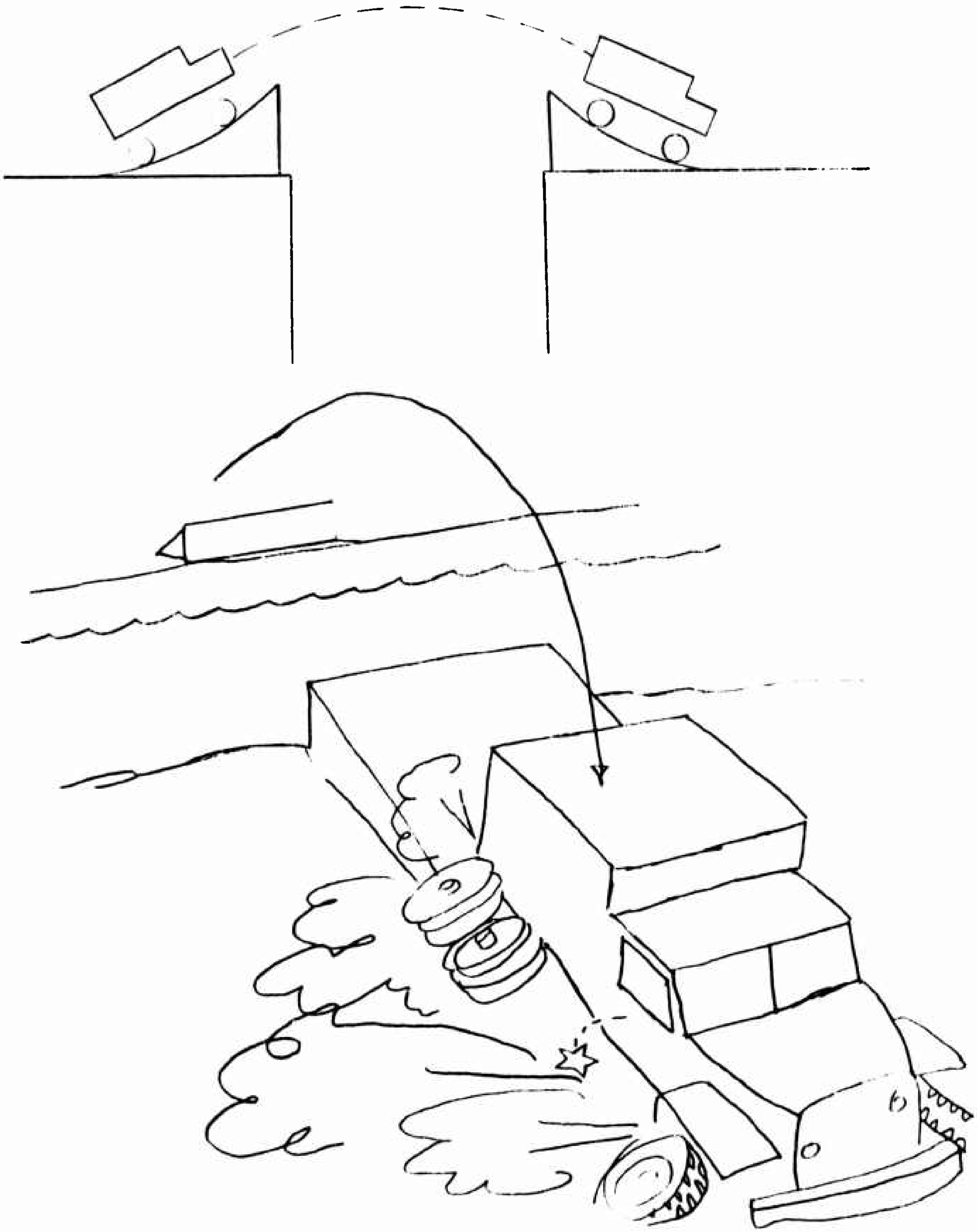

FIGURE 25. PROPERLY CONTOURED LAUNCH AND RECAPTURE RAMPS WOULD AID VEHICLES IN CROSSING SHORT GAPS (ABOVE). CARE MUST BE TAKEN TO CONTROL LAUNCH SPEED TO MATCH RAMP CONTOUR AND GAP DISTANCE TO AVOID CATASTROPHY (BELOW).

1. Simulation Development

As a fundamental step in the development of this methodology, simulations which accurately predict vehicle performance are essential.

a. Mobility Models.

The success of the AMC-71 Mobility Model, even in its preliminary form, demonstrates the potential of such an evaluation tool. This model must be validated, refined and expanded. Among the more pressing areas requiring further development are those associated with:

- Ride.

  An extended ride prediction model must be developed. The present model simulates only rigid-framed vehicles. This model must be extended to account for frame flexibility and articulated vehicles.

- River Crossings.

  One of the most severe obstacles to off-road operation is the negotiation of inland rivers and streams. A model which accurately predicts vehicle performance in the water and while exiting is of prime importance.

- Traction.

  The predictive traction models developed by WES and Bekker are only a first-cut approximation. Since traction is an underlying performance factor for almost all mobility modeling. Valid, accurate traction models which include slip rate must be developed.

- Obstacle Negotiation and Avoidance.

  Present obstacle negotiation and avoidance models are not validated; they must be validated and upgraded where necessary to achieve acceptable engineering accuracy.

o Driver Performance.

We have no adequate driver behavior and performance mathematical models. Most urgent requirements are those associated with visibility, speed selection, response to input shocks and vibration, and route selection.

b. Laboratory Simulations.

There is a companion need for the expansion of laboratory facilities to conduct dynamic simulation testing of elemental components and total vehicle systems. Such laboratory facilities would minimize the subjectivity which enters into the evaluation of vehicle sub-systems, compare competitive configurations against the same baseline, and provide tools for the development of the mobility models discussed above.

o RAM-D.

A great need exists for laboratory facilities which can realistically exercise complete vehicles as well as vehicle sub-systems. The ability to determine functional reliability and durability prior to field performance tests will save time and money as well as improving the RAM-D performance of field systems.

o Man/Machine Interface.

Operational simulators must be developed to evaluate the performance of the man in the vehicle system. The seat simulator at TACOM is but a first step in the development of needed man/machine study tools which can be used to investigate pertinent aspects of human behavior.

o Riverine Performance.

Field tests are extremely expensive. In the case of river crossings in swift streams, they are also dangerous. A river simulator for testing of properly scaled down vehicles would provide a less expensive, safer method for conducting preliminary evaluation of river-crossing designs and techniques, and would also provide a useful

tool for the development of a valid river crossing mathematical model.

- o Vehicle/Soil Interaction.

  Vehicle traction performance models can only be properly evaluated under the controlled conditions available in a soil bin dynamometer facility. Adequate facilities exist at TACOM, WES and Stevens Institute of Technology; they must be properly utilized to develop the relationships needed for the mobility models.

- o Physical Scale Modeling.

  Greater use of physical scale models in the development of vehicles and their sub-systems should be utilized. Many concepts can be investigated in scale model form at a fraction of the full-scale price.

c. Operational Simulations.

There are many operational simulations presently in use. None of these, however, adequately reflect the mobility and RAM-D characteristics of the vehicles involved, and their dependence upon the terrain and the environment.

d. Cost Modeling.

Much work must be done on the establishment of a proper data base before valid cost models can be formulated.

2. Simulation Applications

Once the simulations discussed above are available, they should then be employed in a wide variety of development applications.

- o Computer-Aided Design.

  Proper mathematical performance models and new visualization techniques can be used as a valuable aid in the early concept design phase.

o Equipment Evaluation.

RAM-D and other laboratory simulations can be utilized to evaluate a particular design or to compare competitive configurations. Interfacing of these simulations with higher order combat effectiveness models will provide an evaluation of how the equipment will serve the Army in the field.

o Tactics Development.

The use of new equipment frequently allows the commander to employ his forces in new, more effective ways. Combat and logistical simulations, in addition to evaluating a proposed concept, can be used to determine how best to exploit it in the field.

o Parametric Design Studies.

Systematic evaulations of different but related concepts can be performed to characterize the influence of design factors on vehicle operational performance.

3. Exploratory Prototypes

The proposed use of simulations does not in any way preclude the need to conduct full-scale tests in the field. No model, however sophisticated, can predict all that may occur in the field. There is thus a requirement as a logical complement to the simulation approach for the construction and testing of exploratory prototype vehicles to evaluate definitively new concepts.

IV. CLOSURE

The ideas presented in this report, taken collectively, are considered to constitute a promising starting point for a program of mobility research and development. The next logical steps in the process of implementing such a program are as follows:

1. Analyze the potential risks and benefits associated with each concept presented in Section III.

2. Identify those concepts which appear most promising on the basis of risk-benefit considerations.

3. Identify the pacing technological problems associated with each high benefit/risk potential concept.

4. Design and implement specific research and development projects directed towards the solution of these pacing problems.

APPENDIX A

ORGANIZATIONAL DETAILS AND METHODOLOGY

Participants

Basically, the participants at the workshop fell into three categories: DOD experts in the field of military vehicles or mobility (personnel from this group were assigned the tasks of conducting the briefing orientations, chairing the committees, and conducting the workshop administrative chores); personnel from civilian life with wide technical backgrounds who were known to be innovative in their thinking and accomplishments; and non-technical individuals (who were included in the workshop in order to bring fresh ideas and approaches into the discussions which would require all participants to think in new directions).

The complete list of participants is included in Appendix B. Each participant was sent a briefing statement contained in an orientation letter (Appendix C) and a copy of "Ground Crawling, 1966; the State-of-the-Art in Off-Road Mobility," by C.J. Nuttall. The purpose of the briefing statement was to inform the attendees, of the purpose of the workshop, its scope, and its detailed objectives, and to provide some background information. Mr. Nuttall's text was intended to familiarize attendees with what has been accomplished in the past and to serve as a basic reference for those not up-to-date in ground mobility.

Steering Committee

The Workshop Steering Committee consisted of five persons:

Dr. I. Robert Ehrlich, Stevens Institute of Technology, Chairman
Lt. Col. Frank Cantwell, Headquarters, Army Material Command
Mr. James Carr, Headquarters, Army Material Command
Mr. Howard J. Dugoff, U.S. Army Tank-Automotive Command
Mr. Adam Rula, U.S. Army Engineers Waterways Experiment Station

It was the responsibility of the Steering Committee to plan and organize the sessions, to select and invite the attendees, to outline the content of the briefings, to obtain the briefers, to make all the administrative, housing and social arrangements, and to prepare the written report of the workshop results.

Creative Resource Staff

To aid in the conduct of the workshop, the Steering Committee engaged the services of a Creative Resources Staff. They were:

Dr. Joseph McNeill, Consultant;

Mr. Augustine E. Magistro, U.S. Army Munitions Command, Resource Leader; and

Ms. Marie Panger, Consultant

Dr. McNeill and Mr. Magistro organized and prepared the initial creative session material and briefed the team chairmen prior to the start of the workshop session. Direction of the detailed operations and creative portions of the workshop sessions during the four-day session was provided by Mr. Magistro and Ms. Panger.

Team Organization

The attendees were divided into six teams of six to eight members each. The chairman of each team was preselected and was prebriefed on methods for conducting creative team sessions. Each team was assigned a separate room for the conduct of its deliberations.

The teams stayed together throughout the workshop. The chairman was charged with creating a cohesive team and guiding the deliberations along predetermined paths.

Team selection was conducted in several ways. About half of the participants completed the IPAT Form A test which was scored by the Laboratory of Psychological Studies of Stevens Institute of Technology. From the profiles provided by this test, these participants were assigned to teams to assure heterogeneous team organization on the basis of key personality factors including willingness to experiment, imaginative skill,

and assertiveness. Also, team participants were selected to provide each team with a broad range of technological specialities related to the mobility problems assigned to each team. Each team included at least one person who knew very little about the mobility problem, to bring a fresh outlook to the sessions and cause the "expert" members to examine ideas which they might have otherwise rejected due to bias or preconceived evaluation of merit. A special effort was made to include women participants on each team since their presence causes male members to look in new directions, much removed from their normal course.

Teams were structured so that supervisory personnel were not teamed with working level technical personnel and, in most cases, the team formation followed the rule of a single job level for all members. In those cases where several job levels were present on teams, no serious problems were noted in idea output. The use of the IPAT for team selection reduced the selection problems to a minimum.

Methodology

The main technique for producing new ideas and concepts for improved mobility technology was "brainstorming." This technique is one of the most frequently used by participants whose experience in the intentional generation of ideas is limited. The technique has simple rules which are learned in less than an hour. Thus the participants become effective very quickly. The rules of operation are stated in Appendix D.

The use of brainstorming is designed to help participants to emerge from their technological ruts and to allow them to produce many ideas in a short period of time. Although a typical session will vary in efficiency, from three to ten percent of the ideas generated are significant. Thus, it is the ability of the group to produce hundreds of ideas that make the technique an important technological tool. Also, those participants who are active in the mobility field continue to think of the concepts discussed and to generate new ideas long afterwards, which, by virtue of their position, they are able to apply.

The use of suspended or deferred judgement (no one criticizes an idea, no matter how "ridiculous") and the encouragement of free-wheeling and wild ideas help to produce a widely divergent output that is far removed from the common or traditional lines of thought that may inhibit the production of novel ideas. The continuous flow of ideas from an experienced team of six to eight persons can easily produce more than 100 ideas per hour; inexperienced teams generate about 60 ideas per hour. To offset the idea-recording problem, each participant is provided with many 5" x 8" cards to record his ideas and to make simple conceptual sketches.

Techniques used by teams include deferred judgement, the forced production of a large quantity of ideas, and the use of "hitchhiking" (taking an idea and modifying it to create a new idea). The technique which had the greatest impact in this workshop was the ruling out of criticism or the deferred judgement technique.

The objective of each idea work shop session is the production of many ideas, not just a few carefully considered ones. Evaluation and the selection of the "best" ideas are performed as a later task of the workshop. When the idea or sketch is recorded on a 5" x 8" card, the objective is not to create a work-of-art or an engineering marvel, but to try to communicate the essence of the ideas, to generate raw ideas with as little editorializing as possible, to move along, free-wheeling, to think, to modify, and to expand on the ideas presented.

The workshop idea sessions varied in length from about one to three hours for a total of about 15 hours during the four-day period. The sessions were divided frequently by breaks and coffee at random intervals and the idea car count was checked frequently to determine when idea output was lagging. The teams learned the rules of brainstorming quickly, but early sessions contained many distractions such as editorialization and long idea descriptions.

Team leaders were briefed and instructed on corrective actions at meetings held daily with steering committee members and resource leaders. A key factor in idea generation is the participants' alertness and incentive to generate a large quantity of ideas. The team leader's responsibility is to detect any degradation in the team's performance and to provide corrective action. If the idea output lags, a review of the problem statement is conducted and the problem restated to reduce or refocus the scope.

Briefings

Briefings were held in a number of areas associated with mobility. The briefings were designed to present to the participants a wide variety of concepts that had been tried in the past, the present state of mobility development, the plans for future Army automotive concepts, and the mobility activities of other nations. The briefings presented are listed here by title and author only; detailed briefings may be obtained by contacting the author directly:

Definition of the Mobility Problem - H. Dugoff

Historical Development of Mobile Vehicles - C. J. Nuttall

Engine Developments - D. Latson

Suspension Developments - R. Patek

Foreign Vehicles - D. Fierer

Current Army Vehicle Fleet and Drawing Board Plans - P. Jones

Modular Vehicles - J. Winkworth

Briefing sessions were also held to orient the participants in the creative processes, to introduce the techniques to be used within the teams, and to release their creative potential. Risk-free creative activities were also provided to illustrate the desired team operation. These intial activities allowed participants to experience the use of the key creative tools and to point out typical blocks which inhibit creative thinking.

The participants were provided with a number of mobility briefing documents that were to be used during the workshops to help define the mobility problems to be attacked. The briefing documents described the creative challenge told something about the situation, stated the parameters, and listed some ideas for team consideration. The briefing document gave only enough information so each team member had some initial understanding of the problem and it was anticipated that, as the team operated on the problem, the problem statement would be revised by the team. Copies of the briefing documents used are contained in Appendix D.

Task Assignments

Since the field of mobility is so broad, each team was assigned a special problem area for deliberation in order to narrow the problem to a manageable size. The initial team assignments were to look at future technological advances that may be forthcoming in the next 10-20 years and to determine how these advances might be translated into an improvement in mobility. Each team was assigned different aspects of this problem as follows:

Team #1 — The man/machine/environment interface — Rula, chairman.

Team #2 — Vehicle morphology (shape and arrangement) — Carr, chairman.

Team #3 — Traction systems — Dugoff, chairman.

Team #4 — Propulsion systems — Latson, chairman.

Team #5 — Suspension systems — Patek, chairman.

Team #6 — Control systems — Nuttall, chairman.

Although teams were later allowed to look into areas not assigned, the ideas generated indicate that, in general, each team tended to continue along the path first assigned. The detailed briefing document of each Team is presented in Appendix E.

Next, each team was assigned mobility problem environments where they were to apply the new technological developments discussed previously. Team assignments were as follows:

Problem Area	Teams Assigned
Obstacles	1 and 4
River crossings	1 and 5
Snow	1 and 6
Soft soils	2 and 4
Slippery surfaces	2 and 5
Steep slopes	2 and 6
Dense vegetation	3 and 4
Urban areas	3 and 5
Rough terrain	3 and 6

As an aid to the development of hardware ideas, each team was requested to list the characteristics of each environment. These lists appear in Appendix F.

In each environment, each team was to attempt to think of hardware approaches that utilized concepts incorporating at least one of each of the following approaches:

Wheels
Tracks
Air cushion
Unconventional, novel, or new systems
Hybrid combinations
Add-on kits to existing concepts
External aids (mats, etc.)

Finally, each team developed a set of evaluation criteria and, by examining each idea in turn, assigned a three-level rating: yes, maybe, no. From the "yes" category they then selected and expanded upon the ten concepts that they thought to be best; some teams, however, expanded on more than ten concepts.

It was the intention of the steering committee to have each team work on an actual vehicle concept; however, as the workshop progressed, it was felt that the time would be better spent expanding on the above activities.

The detailed ideas generated are presented in Appendix G and the best concepts selected are presented in Section IV of this report.

Agenda

Only an agenda outline (Appendix C) was distributed to the attendees so that they would not anticipate future events. The master agenda, known only to the steering committee, is contained in Appendix H. Although it was considered to be only a guide, it worked out that it was followed rather well.

Administrative Matters

Most of the administrative matters were covered in the letter of instructions sent to each attendee prior to the meeting. This letter is contained in Appendix C.

General

The brainstorming sessions satisfied the objective of producing a large quantity of material in a short time. More than 75 ideas were selected by the teams for further processing. Additional sessions are recommended to process and improve the ideas developed. Special workshops in each general area discussed in Section IV should be held to amplify the start made at Durham. The organization of the idea improvement and implementation sessions will require a significant amount of planning and, if the effort is inadequate, many ideas will be discarded or overlooked.

In most creative activities where ideas are intentionally generated, the raw output must be examined carefully to see how it can be reduced to practice. The session at Durham did not address itself to the problems of reduction to practice of the ideas generated or a plan of action to achieve idea implementation. This activity is clearly beyond the scope of the authors of this report since it will require the establishment of programs and fundings to investigate the areas and to achieve the objectives presented.

The general consensus of participants was that the objective to uncover innovative ideas that will materially improve Army mobility was achieved and that the experience, though personally fatiguing or frustrating during the early sessions, allows them, for the first time, intentionally to learn to exercise their imagination, to increase their fluency in producing ideas, and to augment their willingness to accept and to be tolerant of new ideas and of those that produced them.

APPENDIX B

PARTICIPANTS
AD HOC WORK GROUP ON INNOVATIVE MOBILITY CONCEPTS

Durham, North Carolina
October 17-20, 1972

Dr. William Banks (313-573-2015)
AMSTA-R
U.S. Army Tank-Automotive Command
Warren, Michigan 48090

Dr. M. G. Bekker (805-966-3486)
224 Islay Street
Santa Barbara, California 93101

LTC B. S. Boudinot (502-624-7150)
Chief, Armor Test Branch
USA Armored Engineering Board
Fort Knox, Kentucky 40121

Mr. Julius H. Braun (213-847-3901)
LOCKHEED CALIFORNIA COMPANY
Market Research Dept. 96-73
Bldg. 63, A-1
P.O. Box 551
Burbank, California 91503

Mr. Finn E. Bronner (919-286-2285)
Environmental Sciences Division
Army Research Office - Durham
Box CM, Duke Station
Durham, North Carolina 27705

Miss Peggy Calder (703-893-3500)
The Mitre Corporation
1820 Dolly Madison Boulevard
McLean, Virginia 22101

*LTC Frank Cantwell (202-OX-7-4948)
Headquarters, AMC
Office of Deputy of Laboratories
Washington, D.C. 20315

*Mr. James Carr (202-OX-7-7301)
Attn: AMCRD-GV
Hdqts. U.S. Materiel Command
Washington, D.C. 20315

Maj. Gen. Chester W. Clark (919-929-6517)
520 Lake Shore Lane
Chapel Hill, North Carolina 27514

Miss Nancy Crane (201-792-2700, Ext.504)
Stevens Institute of Technology
Davidson Laboratory
Castle Point Station
Hoboken, New Jersey 07030

Mr. Tibor Czako (313-573-1440)
U. S. Army Tank-Automotive Command
Surface Mobility Division
AMSTA-RUR
Warren, Michigan 48090

Mr. Owen Douglas (206-597-6111/6242)
AEROJET GENERAL CORPORATION
SES Division
P. O. Box 2173
Tacoma, Washington 98401

Mr. R. Robert Duane (504-255-5925)
Project Engineer
Propulsion Systems
BELL AEROSPACE COMPANY
Michoud Station P. O. Box
New Orleans, Louisiana 70129

*Mr. Howard J. Dugoff (313-573-2015/2378)
U. S. Army Tank-Automotive Command
Attn: AMSTA-RUR
Warren, Michigan 48090

*Dr. I. R. Ehrlich (201-792-2700,Ext.218)
Stevens Institute of Technology
Davidson Laboratory
Castle Point Station
Hoboken New Jersey 07030

---

*Steering Committee

Mrs. Sheila L. Ehrlich (201-833-8316)
859 Columbus Drive
Teaneck, New Jersey 07666

Dr. Ralph Fadum (919-755-2312
Dean of Engineering
229 Riddick Hall
NORTH CAROLINA STATE UNIVERSITY
Box 5518
Raleigh, North Carolina 27607

°Mr. Donald P. Firer
U. S. Army Foreign Science
and Technology Center
AMXST-GE
Charlottesville, Virginia 22901

Mr. Walter Frisch (408-289-2031)
FMC CORPORATION
New Products Division
P. O. Box 1201
San Jose, California 95108

Mr. W. P. Gregory
General Manager
Central Development Division
CLARK EQUIPMENT COMPANY
Box 188
Cassopolis, Michigan 49031

Mr. Robert Hamilton (701-558-1616)
INSTITUTE FOR DEFENSE ANALYSES
400 Army Navy Drive
Arlington, Virginia 22202

Dr. Robert Hess, Director
Highway Safety Research Institute
UNIVERSITY OF MICHIGAN
S. Huron Pkwy & Baxter Road
Ann Arbor, Michigan 48105

Mr. Henry Hodges (702-882-0848/3261)
NEVADA AUTOMOTIVE TEST CENTER
P. O. Box 234
Carson City, Nevada 92701

Mr. Paul D. Jones (313-573-1068)
AMSTA-RHC
U. S. Army Tank-Automotive Command
Warren, Michigan 48090

°Mr. David M. Latson (313-573-1189)
AMSTA-RGT
U. S. Army Tank-Automotive Command
Warren, Michigan 48090

Mr. A. E. Magistro (201-366-1189)
SMUPA-ND-D-B, PICATINNY ARSENAL
Dover, New Jersey 07801

Mr. Edward G. Markow (516-575-3501)
Adv. Surface Transportation
GRUMMAN AEROSPACE CORPORATION
Plant 35
Bethpage, New York 11714

Mr. Melvin Marks
Hq, Army Materiel Command
Office of Deputy for Laboratories
Washington, D. C. 20315

°Mr. Ernest E. Marsh
AMSTA-RGP
U. S. Army Tank-Automotive Command
Warren, Michigan 48090

Dr. Joseph C. McNeill (212-892-3000, x 243)
716 Taft Avenue
No. Plainfield, New Jersey 07063

Mr. James J. Murray (919-286-2285)
Director, Engineering Sciences Division
Army Research Office (Durham)
Box CM, Duke Station
DUKE UNIVERSITY
Durham, North Carolina 27706

Mr. Herman Nadler
Foreign Technology Section
U. S. Army Tank-Automotive Command
Warren, Michigan 48090

Mr. Richard C. Navarin (202-OX-7-2468)
U. S. Army Materiel Command
Research Development & Engineering
Directorate
AMCRD-TV
Washington, D. C. 22203

°Briefer

°Mr. C. J. Nuttall, Jr. (301-8-437-1142)
U. S. Army Engineer Waterways
Experiment Station
P. O. Box 631
Vicksburg, Mississippi 39180

Mrs. Marie Panger
837 Linwood Avenue
St. Paul, Minnesota 55105

°Mr. Ronald A. Patek (313-573-2150)
AMSTA-RUT
U. S. Army Tank-Automotive Command
Warren, Michigan 48090

LTC Melvin D. Remus (202-695-4520/4416)
Headquarters, U.S. Dept. of the Army
DARD-ART
Washington, D.C. 20310

*Mr. Adam Rula (601-8-437-1142)
USA Engineer Waterways Experiment
Station
P. O. Box 631
Vicksburg, Mississippi 39180

Dr. Dieter J. Schuring (716-632-7500)
CORNELL AERONAUTICAL LABORATORY, INC.
4455 Genesee Street
Buffalo, New York 14225

Mr. Leonard Segel (313-764-2168)
Highway Safety Research Institute
UNIVERSITY OF MICHIGAN
Huron Pkway and Baxter Road
Ann Arbor, Michigan 48105

Mr. Paul Spanski
AMSTA-RUR
U. S. Army Tank-Automotive Command
Warren, Michigan 48090

Dr. James H. Taylor (601-887-8596)
National Tillage Machinery Laboratory
U.S. Dept. of Agriculture
P.O. Box 792
Auburn, Alabama 36830

Dr. Bruce Van Deusen (313-686-7400)
Chrysler Defense Division
CHRYSLER CORPORATION
P. O. Box 757
Detroit, Michigan 48231

Mr. James R. Winkworth (313-573-2550)
AMSTA-REN
U.S. Army Tank-Automotive Command
Warren, Michigan 48090

Mr. Robert W. Ziem (202-0X5-0552)
ODDR and E/ET
Room 3D1089
The Pentagon
Washington, D.C. 20301

°Briefer *Steering Committee

St. Clair, Michigan

May 22-23, 1973

Name	Organization	Telephone No.
Jim Carr	AMC	202-384-7186
Howard Dugoff	TACOM	Autovon 273-2015
Rudolf H. Dunec	TACOM	313-573-1147
Robert Loraine	TACOM	313-573-2390
A. E. Magistro	Picatinny	201-328-3775
Lynn Martin	TACOM	Autovon 273-2034
R. P. McGowan	USALWL	301-278-5201
Richard Navarin	USAMC	Autovon 284-9395
C. J. Nuttall, Jr.	USAEWES	601-636-3111, x. 2447
M. Panger	U. of MINN.	612-373-3710
Melvyn D. Remus	OCRD	Autovon 255-4520/4416
D. J. Roesler	USAMERDC	Autovon - Ft. Belvoir 46540
Walter Slabiak	TACOM	Autovon 273-1158
Paul Spanski	TACOM	313-573-1445
Eugene M. Spratke	TACOM	313-573-2491
Jim Winkworth	TACOM	313-573-2550

STEVENS INSTITUTE OF TECHNOLOGY

Castle Point Station, Hoboken, New Jersey 07030

Davidson Laboratory

711 HUDSON STREET

Area Code 201

792 - 2700

APPENDIX C

25 September 1972

Enclosed herewith are further instructions on our forthcoming workshop:

1. Attachment A is a briefing statement.

2. Attachment B is a tentative outline of our program. Note that we plan to adjourn about noon on Friday so that you will be able to make an afternoon flight home.

3. Attachment C contains the administrative details of the meeting.

4. Attachment D is a hotel reservation and information form which should be returned to me by October 6.

5. Attachment E is a personality profile questionnaire which will aid in our grouping of the workshop teams. We would appreciate your filling out the Answer Sheet (Attachment F) and returning it with your hotel reservation form by October 6 also. You are, of course, under no obligation to fill out this form and may elect not to do so, if you in any way feel reluctant.

6. You will also find enclosed, eight 5"x8" cards. Before arrival in Durham, please mark on them:

   a. At least two new technological developments that can be translated into an improvement in surface mobility.

   b. At least two existing mobility systems that, with new technology, could be greatly improved.

   c. At least two new hardware concepts that may provide improved surface mobility.

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CASTLE POINT STATION
HOBOKEN, NEW JERSEY

7. Under separate cover, you will be receiving a report discussing the state-of-the-art on ground mobility. Bring it with you to the workshop and, if you have a chance, look it over before arriving.

I am looking forward to seeing you in Durham and to a most enjoyable and useful workshop.

Very truly yours,

I. Robert Ehrlich

I. Robert Ehrlich

IRE:dp

ATTACHMENT A

WORKSHOP TECHNICAL BRIEFING

1. Objectives:

To review the state-of-the-art of ground mobility and to identify, conceive, and examine possible concepts and approaches for materially increasing the Army's ground mobility for the period 1980-1990 and beyond.

The purpose of this group is to develop ideas, not necessarily workable concepts. If the ideas are innovative and show promise, then research can be initiated to develop them into concepts.

2. Scope:

The scope of the effort will be limited to ground vehicle mobility for off-road cross-country and unimproved roads and trails. It will be oriented toward combat (fighting) and tactical vehicle concepts. Important to mobility but excluded from this effort are:

(1) Amphibious Operations

(2) Containerization

(3) Other Non-Vehicle Logistics Systems: Pipelines - fixed rail - mono-rails - conveyor systems - tramways

The meeting will identify present mobility needs and problems, fruitful research areas and innovative ideas that have the greatest potential for improvements in off-road ground mobility for the future.

The basic tools of mobility and mobile warfare are aircraft, combat and tactical vehicles, general and special purpose vehicles, pipelines, amphibious lighters and barges, and ships. The Workshop will consider those combat and tactical vehicles which maintain contact with the surface either through load-bearing mechanical contact or air cushion.

3. <u>Discussion</u>:

Mobility means many things to many people. Each person sees it in the light of his own knowledge and experience. The term mobility is defined in AR-310-25 as: "A quality or capability of military forces which permits them to move from place to place while retaining the ability to fulfill their primary mission." The same document defines mobile warfare as: "Warfare of movement in which the opposing sides seek to seize and hold the initiative by use of maneuver, organization of fire and utilization of terrain."

For the purposes of this Workshop, a combat vehicle is defined as: "A vehicle with or without armor, designed for a specific fighting function." A tactical vehicle is defined as: "A vehicle with military characteristics designed primarily for use by forces in the field in direct connection with, or support of, combat or tactical operations." The emphasis will be on off-road cross-country operations.

The trend in recent years in the field of ground mobility has been toward product improvement through a program of modification and modernization. This approach is perhaps appropriate from a short-range viewpoint; however, the fact that most of the Army's present fleet was built with 1950-60 state-of-the-art and will be 20-30 years old by 1980 suggests that advances in technology may make feasible new and improved systems that will provide the U.S. combat soldier of the future a tactical advantage.

The task of generating new innovative ideas in the ground mobility field is particularly challenging. There are experts in the field who claim that there is little chance of something "new under the sun" and that brainstorming sessions such as this one can only be "fruitless" and "unprofitable." The challenge for us is to examine the technology base and to prognosticate the future. If there are no new ideas then, perhaps we can confirm the above claims and direct all our resources toward product improvement. On the other hand if new ideas do surface, we may spark a break in the stalemate. Ideally, we should identify technical options that the Army should consider in developing its future ground mobility research and development programs.

ATTACHMENT B

Agenda

MONDAY, October 16

1600-2200	Arrival and check in
1600-1800	Briefing of team chairmen

TUESDAY, October 17

0800-0910	Welcome, Opening Remarks
0910-1030	Briefings:
	Terrain Description Definition of the Mobility Problem Historical Approaches to the Problem
1030-1045	Break
1045-1130	Workshop orientation and charge
1130-1200	Team organization
1200-1300	Lunch
1300-1430	Workshop Session I
1430-1530	Briefing:
	Vehicular Components
1530-1600	Creativity discussion
1600-1700	Workshop Session II
1700-1730	Meeting of Team Chairmen
1830-1930	Get-Acquainted Cocktail Party

WEDNESDAY, October 18

0830-0930	Briefings:
	Current Army Vehicle Fleet
	Vehicles on Drawing Boards
0930-1200	Workshop Session III
1200-1300	Lunch
1300-1345	Briefing:
	Foreign Vehicle Developments
1345-1600	Workshop Session IV
1600-1700	Open
1830- ?	Dinner/Theater, Village Barn Theater (Optional)

THURSDAY, October 19

0830-0930	Development of Rank/Evaluation Criteria
0930-1200	Workshop Session V
1200-1300	Lunch
1300-1400	Open
1400-1700	Workshop Session VI
1630- ?	Banquet

FRIDAY, October 20

0830-1000	Fifteen-minute team reports
1000-1200	Open discussion and development of conclusions

ATTACHMENT C

Administrative Details

1. Dates: October 17-20, 1972 (Tuesday - Friday).

2. Place: Durham Hotel (formerly the Jack-Tar), Durham, N. C. All sessions to be held in the hotel. Please return reservation form.

3. Classification: Presentations, group discussions and report will be "Unclassified."

4. Food and Lodging: A package deal has been made with the Durham Hotel for $16.08 per night ($26.96 double). Please return attached reservation form by October 6. This includes:

   Lodging
   Lunches Tuesday, Wednesday, Thursday
   Coffee and pastry each morning
   Coffee and cake each afternoon
   Cocktail party (Tuesday evening)
   Banquet (Thursday night)
   Guest membership to Durham City Club
   Gratuities and Taxes

   Those not staying at the hotel will be charged $22.71 for all of the above, less lodging.

   Not included:

   Meals Monday
   All breakfasts
   Supper Tuesday
   Dinner/Theater Party Wednesday
   Lunch Friday

   The hotel has a pool (which should still be open in October); tennis and golf may be arranged.

5. Transportation: Limousine service between airport and hotel is $2.50 each way.

6. Dress: Informal for all briefings and workshop sessions (sport clothes). Military participants are requested to wear civilian clothes.

   Dress for Dinner/Theater and Banquet will be business suit (appropriate equivalent for ladies).

ATTACHMENT D

Hotel Reservation Form

Mail to:

Dr. I. Robert Ehrlich
Davidson Laboratory
Stevens Institute of Technology
Castle Point Station
Hoboken, N. J. 07030

1. I plan ___ do not plan ___ to attend the workshop.

2. Please make reservations at the Durham Hotel for the nights of October 16 ___ 17 ___ 18 ___ 19 ___ 20 ___. I desire a single at $16.08/day ___ a double at $26.96/day ____ to be shared with ________________. I do not desire hotel reservations ____.

3. I desire to attend the Dinner/Theater Party Wednesday Evening ("Fiddler on the Roof") at $6.75 per person ____.

4. Enclosed is my personality profile answer sheet ____.
   I would rather not submit my personality profile answer sheet ____.

5. I am interested in the following environmental areas (number in order of preference)

Soft soils and swamps	____
Water Barriers and Land/Sea Interface	____
Rough Terrain	____
Obstacles	____
Mountains	____
Far North	____
Desert	____
Jungle	____
Urban Areas	____
General Purpose Applications	____
Other	____

Name ______________________

Address ______________________

____

____

APPENDIX D

TEAM CHAIRMAN'S ORIENTATION

I. <u>CHAIRMAN'S CHARGE</u> – To present a perplexing situation to an ideation workshop team of six people and lead them to develop idea solutions, not necessarily workable concepts for the situation.

II. <u>GLOSSARY</u>

<u>Creativity</u> is the production of ideas, concepts, creations, or discoveries that are new, original, useful, or satisfying to its creator or someone else in some period of time.

<u>Briefing Document</u> is a technique for preparing a group of people for an ideation session on a perplexing situation.

<u>Creative Stimulators</u> are methods and probes that promote creative thinking and aid the creative process.

<u>Decision Making</u> is the process of choosing between alternative ways of getting a job done.

<u>Perplexing Situations</u> are those jobs, personal, or social circumstances that a person is aware of and realizes that some action on his part is necessary.

<u>Warm-ups</u> are group exercises used by the Chairman and participants prior to an ideation session.

III. <u>HOW TO CHAIR THE WORKSHOP</u>

1. You, the Chairman, will provide the participant with a number of perplexing situations that GMI are facing. The briefing document describes (for each participant) the creative task; tells something about the situation, part or product; state the

parameters; and lists sample ideas.

2. The briefing document will be prepared by the workshop chairman. The objective of the workshop is to generate ideas rather than details; therefore, the briefing document gives the participant only enough information so he can generate solutions for the task.

3. Each participant should start the "Work Shop Session" with five or more "raw" ideas for solving the challenge. For each idea, just a quick sketch or a few words on 5"x8" cards is needed. Please put only one idea per card and prepare them at the beginning of the session.

4. During the session, the participant will have an opportunity to discuss his ideas and generate additional ones. A supply of cards and pens will be at each table.

5. Every new idea combines one element with another element in a new way to yield the third element, the new idea. The more raw ideas we have floating around, the greater our chance for coming up with new ones. Keep the ideas flowing from each participant's expertise, and, particularly, life experiences.

6. The purpose of each Work Shop session is to create ideas, not to judge them. Therefore, you should defer judgment and strive for fluency, free-wheeling, and serendipity. The by-products of initial ideas are often better than the original ideas.

7. The objective of each "Work Shop" session is to produce a quantity of ideas, not just a few carefully considered ones. Our objective is 300 ideas per session. Quantity brings quality.

8. In the Work Shop sessions, insist that each new idea that comes up be put on a card with a quick sketch and/or a few words. Our purpose is not to create a work of art or an engineering marvel. We just want the participant to communicate the essense of his idea. Each card should be dated, initialed, and put in the center of the table. Give each idea as little engineering thought as possible.

9. Idea concepts are what we are looking for, so move along by free-wheeling and generating related ideas. Get the ideas into the hopper, but have the participant express them verbally to the group.

10. Keep each participant on the idea being generated by the work shop group. Each contributions will be much more valuable if the group could explore them. The chairman will lead the way.

11. Keep the group loose. Try smile breaks every 30 minutes.

12. Relax and enjoy yourselves. Creating ideas can be fun for both the chairmand and participants.

IV. THINGS TO WATCH OUT FOR

1. Check all room conditions for the comfort of participants.

2. Repeat the instructions prior to each ideation session. Remind everyone that the objective is idea solsutions to the perplexing situation--not critical comments.

3. Be certain each idea is written on a 5" x 8" card that is dated, initialed, and immediately turned in.

4. Set the expected output of ideas for each session.

5. Start on time and end on time.

6. Keep the session moving by calling on each person to participate in a clockwise rotation.

7. If idea production lags, change the creative stimulator or technique.

V. <u>PROBLEM SOLVING MODEL AND THE PHASES THE CONFERENCE WILL COVER</u>. SEE EXHIBIT A AND B.

VI. <u>CREATIVITY LECTURE</u> (slides)

a. What is it?

b. What stifles creativity?

c. What enhances creativity?

d. Group effort for planned innovation.

VII. <u>CREATIVE STIMULATORS AND TECHNIQUES</u> (vary these during the workshop session)

1. <u>Rules of Deferred Judgement</u>

a. <u>CRITICISM IS RULED OUT</u>: Judgement is suspended until a latter screening or evaluation session. Allowing yourself to be critical at the same time you are being creative is like trying to get hot and cold water from one faucet at the same time. Ideas aren't hot enough; criticism isn't cold enough. Results are tepid.

b. <u>FREE-WHEELING IS WELCOMED</u>: The wilder the ideas, the better. Even off-beat, impractical suggestions may "trigger" in other panel members practical suggestions which might not otherwise occur to them.

c. <u>QUANTITY IS WANTED:</u> The greater the number of ideas, the greater likelihood of winners. It is easier to pare down a long list of ideas than puff up a short list.

d. <u>COMBINATION AND IMPROVEMENT ARE SOUGHT</u>: In addition to contributing ideas of their own, panel members should suggest how suggestions by others can be turned into better ideas or how two or more ideas could be combined into a still better idea.

2. Laws of Association (use questions to show:)

   a. Contrast (comparison, show unlikeness, compare by observing differences).

   b. Contiquity (close proximity).

   c. Similarity.

3. Idea-Spurring Questions - Use these to concentrate on a particular idea.

   PUT TO OTHER USES? New ways to use as is? Other uses if modified?

   ADAPT? What else is like this? What other ideas does this suggest?

   MODIFY? Change meaning, color, motion, sould, odor, taste, form, shape? Other changes?

   MAGNIFY? What to add? Greater frequency? Stronger? Larger? Plus ingredient? Multiply?

   MINIFY. What to subtract? Eliminate? Smaller? Lighter? Slower? Split up? Less frequent?

   SUBSTITUTE? Who else instead? What else instead? Other place? Other time?

   REARRANGE? Other layout? Other sequence? Change pace?

   REVERSE? Opposites? Turn it backward? Turn it upside down? Turn it inside out?

   COMBINE? How about a blend, an assortment? Combine purposes? Combine ideas?

4. FURTHER IDEA-SPURRING QUESTIONS

IDEA NEEDLERS

How much of this is the result of custom, tradition, or opinions?

Why does it have this shape?

How would I design it if I had to build it in my home workshop?

What if this were turned inside out? reversed? upside down?

What if this were larger? higher? longer? wider? thicker? lower?

What else can it be made to do?

What other power would work better?

Where else can this be done?

What if the order were changed?

Suppose this were left out?

How can it appeal to the senses?

How about extra value?

Can this be multiplied?

What if this were blown up?

What if this were carried to extremes?

How can this be made more compact?

Would this be better symmetrical or asymmetrical?

In what form could this be?

Liquid, powder, paste, or solid?
Rod, tube, triangle, cube or sphere?

Can motion be added to it?

Will it be better standing still?

What other layout might be better?

Can cause and effect be reversed? Is one possibly the other?

Should it be put on the other end or in the middle?

Should it slide instead of rotate?

Demonstrate or describe by what it isn't.

Has a search been made of the patent literature? trade journals?

Could a vendor supply this for less?

How could this be made easier to use?

Can it be made safer?

How could this be changed for quicker assembly?

What other materials would do this job?

What is similar to this but costs less? Why?

What if it were made lighter or faster?

What motion or power is wasted?

Could the package be used for something afterwards?

If all specifications could be forgotten, how else could the basic function be accomplished?

Could these be made to meet specifications?

How do noncompetitors solve problems similar to this?

5. BIONICS: Ask yourself, "How is this done in nature?" Nature's scheme of things is revealed to those who search. (Note: This technique may come into play when utilizing analogies.)

6. REVERSE BRAINSTORMING: Sometimes useful prior to an ideation session. It consists of being critical instead of suspending judgement.

   (a) List all the things wrong with the operation, process, system, or product.

   (b) Systematically take each flaw uncovered and suggest ways of overcoming it.

7. INSPIRED (BIG DREAM) APPROACH: A "breakthrough" approach which sometimes leads to spectacular advancements.

   (a) Think the biggest dreams or technological advances possible.

   (b) Read, study, and think about every subject connected with your big dream--and do so regularly, persistently, continually.

   (c) Drop down a dream or so, then engineer your dream into reality.

   The objective is to make the greatest possible achievement for human benefit.

8. ATTRIBUTE LISTING: A technique used principally for improving tangible things.

   (a) Choose some object to improve.

   (b) List the parts of the object.

   (c) List the essential, basic qualities, features, or attributes of the object and its parts.

   (d) Systematically change or modify the attributes.

9. FORCED RELATIONSHIP: A method which attempts to force association.

   (a) Isolate the elements of the problem at hand.

   (b) Find the relationships between/among these elements (similarities, differences, analogies, cause and effect).

(c) Record the relationships in organized fashion.

(d) Analyze the record of relationships to find the patterns (or basic ideas) present. Develop new ideas from these patterns.

VIII. CREATIVITY STIFFLERS

1. Killer Phrases. Below is a list of some of the killer phrases. You know them well; everyone does who has ever attended a meeting, but read the list over carefully. You will hear echoes from wasted conferences, and you will know what to avoid in the future. In an ideation session, killer phrases are strictly ruled out. In fact, place a bell in the center of the table; whenever a killer phrase pops up, the bell should be rung by the nearest person. Here they are:

We've never done it that way before.....

It won't work.....

We haven't the time.....

We haven't the manpower.....

It's not in the budget.....

We're not ready for it yet.....

All right in theory, but can you put it into practice?

Too academic.....

What will the customers think?

Somebody would have suggested it before if it were any good.....

Too modern.....

Too old-fashioned.....

Let's discuss it some other time.....

You don't understand our problem.....

We're too small for that.....

We're too big for that....., etc., etc., etc.

2. Killer Glances. Beside the killer phrase, you have to ring the bell on the killer glance and the man who is disturbed by repetition. Repeating an idea may spart a new chain reaction--so encourage it.

3. Apologetic Phrases (Self-Killer Phrase). A twin brother to the killer phrase is the apologetic phrase you often use to give a deadly introduction to your own idea. In an ideation session it's outlawed too, but don't ring the bell. Notice how these killers disappear as you cultivate a creative atmosphere receptive to new ideas.

This may not be applicable but.....

While we have only made a few preliminary tests.....

This may not work, but.....

This approach is screwy, but.....

It isn't clear that we need this, but.....

I don't know if the money can be appropriated, but.....

It might be a dead end, but.....

Would it hurt if we did.....

Do you suppose it would be possible to.....

It may sound hair-brained, but.....

It may take a long time, but.....

I don't know just what you want, but.....

You probably have ideas about this too, but.....

You aren't going to like this, but.....

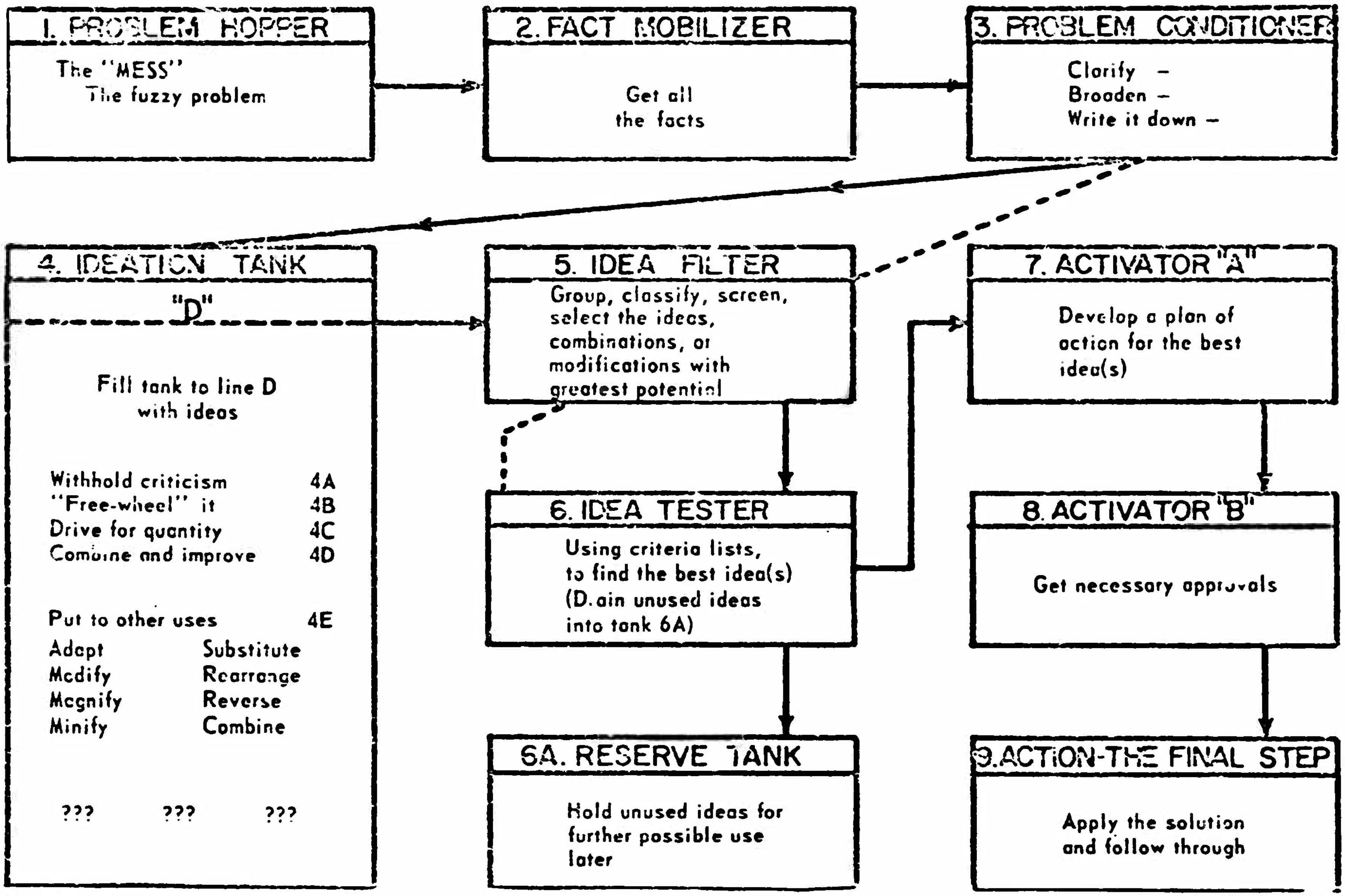
This is contrary to policy, but.....

This may not be the right time, but.....

This idea seems useless, but.....

Exhibit A

CREATIVE PROBLEM SOLVING "FLOW DIAGRAM"



EXHIBIT

city "X" construct
(overpass)
roadway
at intersection
& Vine Streets?

or

RECORD THE FACTS

Intersection is 30 ft. wide.

Flow of traffic is 200 vehicles per hour in all directions.

Both streets have approximately the same traffic.

Traffic control consists of stop signs in all directions.

Accident rate is one per week.

EXAMINE THE FACTS

What is the CAUSE for an overpass or underpass?

Two or more vehicles attempting to occupy the same space at the same time.

What is the NEED?

1. To protect vehicles & occupants.

BRAINSTORM (CREATE)

What will eliminate the CAUSE?

1. Eliminate vehicles on both streets.
2. Eliminate vehicles on Vine St.
3. Require all vehicles to make right turns.
4. Construct underpass.
5. Construct overpass.

What will eliminate or modify the NEED?

All of above will eliminate need.

6. Electric traffic signals.
7. Replace stop signs on Vine with yield signs.

— Etc. —

CRITERIA

Alternatives	Cost	Safety	Control of Traffic	Acceptance	Summary	Select
Present Method	9	3	2	4	18	
1	5	10	5	0	20	
2	9	6	5	0	20	
3	9	6	5	1	21	
4	1	9	10	4	24	
5	1	9	10	4	24	
6	8	9	5	8	30	✓
7	9	1	1	2	13	

DEVELOP THE PLAN (PROPOS

Recommend Installation of electric traffic signals time-phased for peak traffic hours.

Vehicular use of intersection and accident rate do not warrant large expenditure of city "X" funds in the construction of overpass/underpass at

Brainstorming pulls better ideas at less expense

Engineers looking for proved ways of garnering ideas for products might well turn to programmed invention, a kind of brainstorming that includes expert evaluation of new ideas

"Now let's combine a typewriter with a bottle of seltzer. Very interesting, isn't it?"

"Okay, write the problem down Chuck, let's see a picture." (Chuck shows a picture of typewriter and seltzer. Everybody laughs.)

"All right, you guys, when I say 'go,' open your heads and dump out every possible way you can think of to keep something wet. And don't forget incantations and magic spells."

This dialogue may read like a scene from Rowan and Martin, but it is taken from a Programmed Invention session at Van Dyck Corp. (VDC, Southport, Conn.). There, six men from six disciplines, responding to the proddings of a skilled session leader, are developing product ideas for a leading industrial company that ranks well up in *Fortune* magazine's 500 largest U. S. businesses.

All for new ideas. The creative session is just one of three stages in Programmed Invention (PI) being developed at the company. The goal of PI, as it's more commonly called at Van Dyck, is to solve a problem or to come up with product ideas specifically tailored to a client's special capabilities and long-range growth plans.

Ken Van Dyck, president of VDC, emphasizes that PI is giving companies a new management tool to get at evaluated ideas for a lot less money than before. So far, Van Dyck Corp has conducted 30 Programmed Invention efforts under the guidance of R. Donald Gamache, a vice-president who has developed many of the methods.

"Our approaches have worked well in these cases," he says. "And I believe they can be applied by any company looking for a proven method for coming up with creative solutions to problems."

Ideas to save money. The basic philosophy of PI is: While ideas are cheap and can come with lightning speed, the effort required to develop an idea into a workable process or marketable product is expensive and involves painstaking analytic work.

Therefore, to ensure that it is spending its development money prudently, a company should first make a small investment in obtaining a large number of ideas. With many to choose from, the company increases its probability of finding some really good ideas.

The creative session is the phase of Programmed Invention that produces a large number of ideas. It is preceded by a careful definition of the problem and succeeded by a critical examination and sifting of the ideas to isolate the few that are worthy of an expensive engineering effort.

Defining company needs. Gamache places great emphasis on defining the company's problem or product needs and relating these to capabilities.

"Every company has a different personality. Even if two companies have the same production equipment, their manufacturing capabilities will be different. For example, one may be capable of adhering to much closer tolerances than the other," he says.

From the plant study, which involves the company's top management, the Van Dyck staff produces a briefing document. This gives the specialists who will attend the creative session the technical, marketing, and economic information they need about the company to give focus to their ideas.

The briefing document, a looseleaf notebook running some 25 to 30 pages, is terse. If the goal of the creative session is product ideas, the document may indicate that the company has, for instance, expertise in metal plating, die casting, and extrusion, that it relies on regional distributors to market its products, that it targets a 6% return on invested capital, and that the product should sell for $15 to $25.

If the client wants to improve a product process instead of creating a new product, the briefing document will concentrate on engineering parameters. Marketing and sales goals are thus played down.

Participants in the creative session receive the document at least a week before the session. This is enough time to give them a chance to think about the problem and subject it to a subconscious gestation period—but it is not enough time to allow them to dismiss the project.

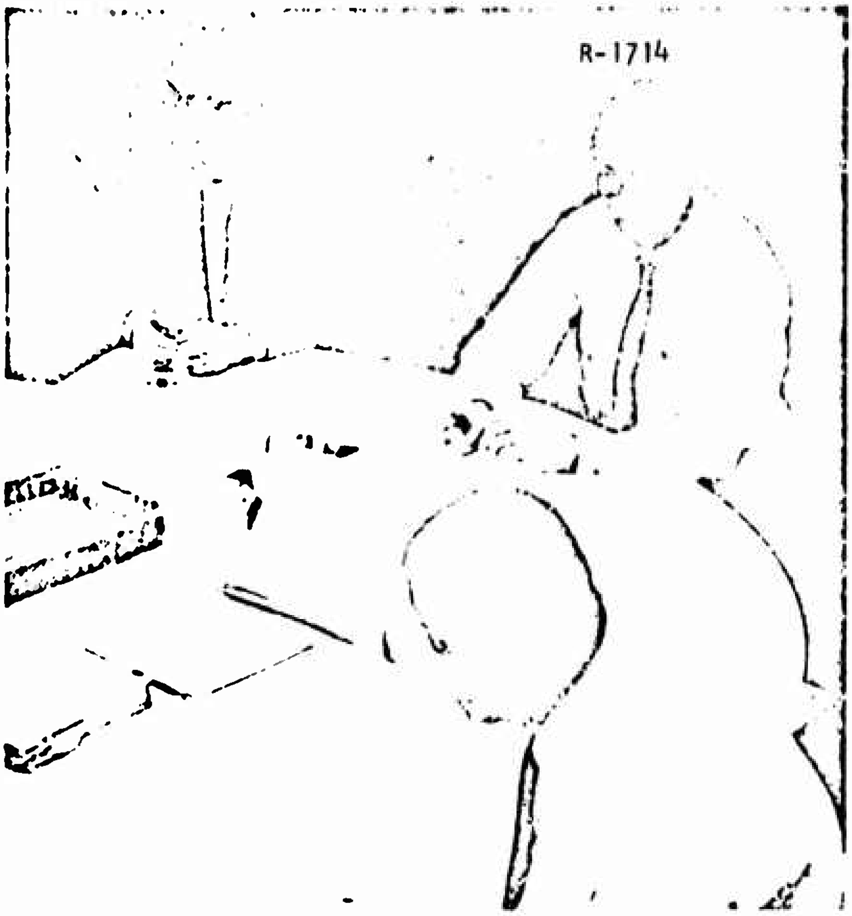
Rules of the game. Gamache usually selects six individuals and a session leader for creative sessions. If the group is larger, there is danger that it will break down into smaller groups, he warns. Then, if individuals do not get a chance to talk to the group as a whole, they will talk to a neighbor, a waste of their potential contribution.

Also, no one should be an "expert" in the field under consideration. If the client manufactures appliances, for example, nobody in the creative session should have made a career in the appliance industry. "Experts can tell you why every idea won't work," says Gamache.

Participants always come from different disciplines. "We are all programmed by our educations and work experiences," says Gamache. "Ask 10 mechanical engineers to propose solutions to a problem. Together, they may come up with 30 possible answers. Ask another 10 mechanical engineers to solve it, and they will also come up with 30 solutions, but most of them will be duplications of the first group. Now ask 10 chemical engineers to solve the same problem, and many of their 30 solutions will be different from those offered by the mechanical engineers."

Differences a must. If you want a wide range of solutions to choose from, you need an interdisciplinary group. No matter how talented people are, variety and objectivity are essential.

On a program dealing with new concepts in shipbuilding for U. S. Steel, for example, the creative team was made up of aircraft designers,



Donald Gamache (front) tosses an idea into the hopper at a Van Dyck creative session. With him are specialists in marketing, engineering, industrial design

materials handling experts, systems analysts, metallurgists, architects, and other specialists in related fields. And during the idea-generating phase, no one knew the first thing about shipbuilding.

Once a diverse group is assembled, it is necessary to create an easy atmosphere in which ideas will flow freely, explains Gamache. Participants must feel they are having a good time. And they must feel free to laugh at themselves and at each other, without any embarrassment.

"There must be no pressure points," he adds. "By pressure points I mean that all participants must be peers. You could never mix the vice-president of engineering and an engineer on his staff in the same group. No one should feel that somebody is looking over his shoulder."

Breaking the ice. Those who have tried to work with idea generating groups frequently find it hard to get the session going. One technique Gamache has applied satisfactorily is the imposition of artificial pressure. It may sound like a contradiction of his admonition to make the session fun, but the idea is simply to create a competitive atmosphere by asking participants to write down as many ideas as they can in a few minutes.

Once you have this base of raw ideas to work from, the members of the group will spin off variations and mutations in widely diverging patterns, says Gamache. They will add to each other's ideas and create new ones, bringing to bear on the problem a lifetime of knowledge and experience that is unconnected with it.

"We have never thrown anybody out of a creative session," says Gamache, "but we have been tempted to at times." The man they might throw out is the one who is negative, who judges ideas and tells you why they won't work.

"The most successful creative sessions are held in the morning, from about 9:30 to noon," explains Gamache. "You can't successfully get a man to carry on with a creative session at lunch . . . and he is not as fresh in the afternoon.

"And beware of the blue Monday and TGIF syndromes. If we schedule a creative session on Monday or Friday, nothing happens. Friday afternoon is a total loss!" he says.

Evaluating ideas. The final step again involves an interdisciplinary group of individuals. But these are experts in the technology or product area involved. Usually, the group includes appropriate client executives representing general management, manufacturing, engineering, or marketing. "At this stage, we call in the top men in the field to help evaluate the most promising ideas that came out of the creative sessions. If the product involves optics in its design, for example, we will call in the best optics man we know," says Gamache.

With this careful evaluation of ideas, the best are selected. Van Dyck's professional staff of engineers, industrial designers, marketing experts, and modelmakers then develop models and supporting technical, marketing, and sales information to support the ideas that have evolved from the program.

An eye to marketing. "Too many engineers see their good ideas come to nought because they fail to make a marketing case for them," Gamache points out. "You must talk the language of top management when you are trying to sell an idea to them."

Ken Van Dyck, VDC president, sums up with two observations. Programmed Invention has provided guidelines for management for product-acquisition programs. In one situation, the briefing document was used almost verbatim as a guide.

Van Dyck also says that the "big attraction of Programmed Invention to management has to do with good-sized monetary savings." PI gets product concepts up to the Go/No-Go stage for far less money than is possible in most companies.

The program "idea packages" combine objective internal-external professional input from marketing, financial, engineering, industrial design, manufacturing, and management viewpoints in a balance seldom achieved through routine product-development channels.

For a few thousands of dollars, fresh product concepts get the full treatment and are presented in an easily assimilated form to management. **(7.11; 7.32)**

Copy of index code (heavy type numbers) available for 50¢ from Reader Service Department.

Exhibit D

HOW CREATIVE SESSIONS FUNCTION

Have you ever participated in small impromptu groups, dreaming of ways to play a trick on someone? Or have you experienced the delight of proposing an outlandish scheme, having it immediately topped by some else, and then, through sheer inspiration, presenting an even more outlandish trick yourself? If so, you know the bouyant spirit and exhilaration permeating such an atmosphere. Occasionally, the resulting ideas are truly ingenious—creations brought into existence as a direct result of the mutual support and encouragement throughout the group.

Let's see how to apply the same technique in engineering activities to create the new ideas so necessary for progress. A look at why bull-sessions are so conducive to imaginative adventure may furnish some clues. The sessions create an atmosphere that allows you to . . .

Express the problem generally—free from all side specifications or conditions.

Assume that every idea will work.

Search for ideas without restrictions.

Participate with a competitive spirit.

Capitalize on the mutual atmosphere of praise and encouragement.

Carry these ground rules over into a creative session and you can tackle any tough engineering problem. Just remember these five simple rules.

Besides being a source of new ideas, these sessions are also valuable for their stimulative effect on the group and on each individual. When this effect is felt in a large degree, you know that creativity has had the best opportunity to exhibit itself. And if truly successful, this stimulation will be carried back to the job. Don't expect an immediately useful idea from every session. But do expect that as you continue to hold these sessions the percentage of useful ideas will increase. For your creative talents respond to exercise just as do all your other abilities.

After the creative session, evaluate each idea carefully. Ask yourself such questions as: Could this be made to work if I made it smaller? What if I used a different material? What if I changed its shape? What if I combined these two ideas? Finally, select the most promising ideas for further investigation and analysis.

Remember: Your creative efforts are stifled when the immediate response is either no or a look of derision. When this occurs, creativity crawls back into its little shell, and old blueprints, old approaches, and old techniques continue on as always. Use these creative sessions to break loose from inhibitions. Exercise your imagination. Have the will to succeed. And who knows, you may develop a product that will put the competition to shame. Try it!

APPENDIX E

BRIEFING DOCUMENT — TEAM #1

Workshop Session 1

Man/Machine/Environment Interface

I. Statement of Perplexing Situation:

What are the possible future (1980-1990 and beyond) technological advances which might be translated into an improvement in vehicle mobility from the standpoint of the vehicle man/machine/environment interface?

II. Background Information

A vehicle cannot be operated properly without an effective man/machine/environment interface. Poor interfaces prevent the driver from operating his vehicle at its optimum level of performance. Tasks of this interface are to:

a. Provide adequate visibility to the operator of the vehicle displays and the terrain.

b. Provide a link between the operator and the controls of the vehicle.

c. Provide feedback of driver actions.

d. Keep the temperature surrounding the crew at a comfortable level.

Improvements in the man/machine/environment interface will allow for more efficient operation of the vehicle and the ability of the driver to obtain the maximum from the vehicle's capabilities.

III. Basic Questions

a. What are the characteristics of a good (or bad) man/machine/environment interface?

b. What additional influences does the m/m/e inteface have on vehicle operation?

c. How does nature solve the m/m/e interface problem?

d. What are the shortcomings of present m/m/e interfaces?

e. What are the basic elements of the m/m/e interface? How may each be improved?

f. What is closely allied to the m/m/e interface that exists in other fields (housing, machinery, etc.) that can be applied to vehicle design?

IV. Sample Ideas

a. TV to expand visibility.

b. Light amplifcation systems.

c. Force feedback systems.

d. Environmentally controlled clothing.

BRIEFING DOCUMENT — TEAM #2

Workshop Session I

Vehicle Morphology

I. Statement of Perplexing Situation

What are the possible future (1980-1990 and beyond) technological advances which might be translated into an improvement in mobility from the standpoint of vehicle morphology (shape and arrangement)?

II. Background Information

Vehicles are designed to do a multiplicity of tasks: Logistical, combat, reconnaissance, command carriers, personnel carriers, communications, etc. The shape and arrangement influence greatly the ability to perform these tasks as well as the way the vehicle conforms to the terrain in which it must operate.

Improvements in morphology will allow for an improved vehicle/terrain interface, improved carrying capacity, etc.

III. Basic Questions

a. What are the characteristics of a good (or bad) vehicle shape and arrangement?

b. What additional influence does shape and arrangement have on vehicle operation?

c. How does nature approach the morphology problem?

d. What are the shortcomings of present morphology?

e. What are the basic elements of vehicle morphology? How may each be improved?

f. What is closely allied to morphology in vehicles that exists in other fields (housing, machinery, etc.) that can be applied to vehicle design?

IV. SAMPLE IDEAS

a. Long, thin vehicles to negotiate forests.

b. Multiple units to conform to rough terrain.

c. Horizontal as well as vertical suspension systems to reduce transverse accelerations.

d. Very low silhouette vehicles for small target areas.

e. Longer width vehicles for high performance in surf, soil and snow.

f. Snake-like mass exchange vehicles.

BRIEFING DOCUMENT — TEAM #3

Workshop Session I

Traction System

I. Statement of Perplexing Situation

What are the possible future (1980-1990 and beyond) technological advances which might be translated into an improvement in mobility from the standpoint of Traction Systems?

II. Background Information

Traction System of ground vehicles perform the following functions:

a. Generate the forces between the vehicle and the terrain which accelerate the vehicle.

b. Generate the forces between the vehicle and the terrain which decelerate and stop the vehicle.

c. Provide the stabilizing and control forces for the vehicle.

Improved traction systems provide greater traction, show more resistance to terrain damage, lighter, more reliable, etc.

III. Basic Questions

a. What are the characteristics of a good (or bad) suspension system?
b. What additional tasks are required of the traction system?
c. How does nature approach the traction problem?
d. What are the shortcomings of present traction systems?
e. What elements make up the traction system? How might each be improved?
f. What is closely allied to a traction system that appears in other fields (housing, machinery, etc.) but is not used on vehicles?

IV. Sample Ideas

a. New traction materials.

b. Expendable traction elements.

BRIEFING DOCUMENT — TEAM #4

Workshop Session I

Propulsion Systems

I. Statement of Perplexing Situation

What are the possible future (1980-1990 and beyond) technological advances which might be translated into an improvement in mobility from the standpoint of Propulsion Systems?

II. Background Information

Propulsion Systems of ground vehicles perform the following functions:

a. Provides the propelling energy (torque, rpm, etc.).
b. Enables the vehicle to move in a controlled manner (forward, backward, fast, slow).
c. Transforms the energy emanating from the source into the form necessary for the task presented.

Improved propulsion systems should allow for lower fuel consumption, lighter weight, lower cost, improved reliability, greater responsiveness, etc.

III. Basic Questions

a. What are the basic characteristics of a good (or bad) propulsion system?
b. What secondary tasks are required of the propulsion system?
c. How does nature approach the propulsion problem?
d. What are the shortcomings of the present propulsion systems?
e. What elements make use of the propulsion system? How might each be improved?
f. What is closely allied to a propulsion system that appears in other areas (housing, machinery, etc.), but is not used on vehicles?
g. How will environmental considerations effect the propulsion systems?

IV. Sample Ideas

a. Direct energy conversion
b. Fuel cells
c. Exotic fuels
d. Rotary engines
e. Infinitely variable torque conversion
f. No ground contact systems

BRIEFING DOCUMENT - TEAM #5

Workshop Session 1

Suspension Systems

I. Statement of Perplexing Situation

What are the possible future (1980-1990 and beyond) technological advances which might be translated into an improvement in mobility from the standpoint of Suspension Systems of Ground Vehicles.

II. Background Information

Suspension systems of ground vehicles perform the following functions:

a. Smooths out the road roughness.

b. Provides the link between the traction elements and the propulsion system.

c. Provides the controlling forces.

Improved suspension systems should allow higher speeds over rough terrain, greater ease of handling, finer control, greater stability, reduced weight, etc.

III. Basic Questions

a. What are the basic characteristics of a good (or bad) suspension system?

b. What additional tasks are there required of the suspension system?

c. How does nature approach the suspension problem?

d. What are the shortcomings of present suspension systems?

e. Under what conditions would we desire no suspension system?

f. What is closely allied to a suspension system that appears in other areas (housing, machinery, etc.) but is not used on vehicles.

g. What elements make up the suspension system? How might each element be improved?

IV. Sample Ideas

a. Force feed-back actuators.

b. New Plastics with high energy absorbing capabilities.

c. Miniature computers.

d. New Manufacturing processes to reduce costs.

BRIEFING DOCUMENT — TEAM #4

WorkshopSession I

Control Systems

I. Statement of Perplexing Situation

What are the possible future (1980-1990 and beyond) technological advances which might be translated into an improvement in mobility from the standpoint of Control Systems.

II. Background Information

Control Systems of ground vehicles perform the following function:

a. Guide the vehicle over the terrain with a minimum of effort.

b. Anticipate obstacles.

c. Provide a stabilizing influence.

d. Provide feedback information to the operator of the state.

Improved Control system would need less operator skill, be in a smaller reliable package.

III. Basic Questions

a. What are the characteristics of a good (or bad) control system?

b. What additional tasks are acquired of a control system.

c. How does one approach the control system problem?

d. What are the shortcomings of the control system? How might these be improved?

e. What is closely allied to the control system that appears in other fields (trains, housing, nature) but is not used on vehicles?

f. What functions does the control system perform?

g. What are the attributes of the most effective system today?

IV. Sample Ideas

1. No operator required.

BRIEFING DOCUMENT — ALL TEAMS

Workshop Session II

Review and Continuation

In light of the previous briefings and a review of the ideas generated by the other teams, what might you add to the list generated in Session I for any of the six areas:

- Suspension Systems
- Propulsion Systems
- Traction Systems
- Control Systems
- Vehicle Morphology (shape and arrangement)
- Man/Machine/Environment Interface

BRIEFING DOCUMENT — ALL TEAMS

<u>Workshop Session III</u>

How might these new technological developments, in coordination with existing technology, be applied to attack the mobility problems presented by:

PROBLEM AREA	TEAMS ASSIGNED
Obstacles?	1 and 4
River crossings?	1 and 5
Snow?	1 and 6
Soft soil?	2 and 4
Slippery surfaces?	2 and 5
Steep slopes?	2 and 6
Dense vegetation?	3 and 4
Urban areas?	3 and 5
Terrain roughness?	3 and 6

Consider the following approaches:

Wheels

Tracks

Air cushion

Unconventional, novel or new systems

Hybrid combinations of the above

Add-on kits to the above

External mobility aids (winches, portable mats, etc.)

APPENDIX F

CHARACTERISTICS OF VARIOUS TERRAIN OBSTACLES

Obstacles

1. May be by-passable sometimes.
2. Come in all sizes and shapes (width, height, breath).
3. May be man-made or natural.
4. May provide cover and concealment.
5. May immobilize.
6. Deterrent to speed or direction.
7. Sometimes have a definitive pattern.
8. Usually occur in strong soils.
9. Sometimes impairs visibility.

Rivers and Streams

1. Banks - steep, wet, slippery, depending on soil.
2. Current degrades control afloat.
3. Entrance and exit difficulty.
4. Sand bars.
5. Marsh near banks.
6. Waves on wide rivers.
7. Water/soil transition zone.
8. Vegetation at banks, into river.
9. Meanders - outside banks steep; inside banks gentle, but soft.

Snow

1. Frictional when dry; cohesive when wet.
2. Large variations in strength due to age, altitude, temperature and wind environment.
3. Friction is minimum when a water interface is created due to pressure or heat.
4. Large percentage of voids filled with air.
5. Conceals obstacles.
6. Surface may be rough or smooth.
7. Associated with cold ambient temperatures.
8. Insulates underlying soil, sometimes preventing it from freezing.
9. Sometimes compactable.
10. Vegetation usually defolated.

Soft Soils

1. Seasonally dependent.
2. Generally associated with near-level terrain.
3. May vary in grain type and water content.
4. Deformable.
5. Little induced vibration (no roughness).
6. Low traction.
7. Often has low bearing capacity.
8. Adheres to vehicle components (sticky).
9. May be in layers with the soft soil above or below a firm layer.
10. High water content.
11. Usually homogeneous.
12. Rutted after traffic.
13. Surface strength degrades quickly with traffic.
14. If dry, usually wind blown and traffic increases strength (beaches and deserts).
15. Subject to freezing which brings increased bearing capacity, but severe roughness if previously rutted.

Slippery Slopes

1. Generally wet.
2. Frequently a soft, slippery layer over a firm undersurface.
3. Frequently occurs near rivers or streams.
4. If ice or snow covered, surface is hard but slippery.
5. Vegetation may provide the moisture to generate the slipperiness.

Steep Slopes

1. Usually firm undersurface structure.
2. Frequently rock- or boulder-strewn.
3. May have vegetation support.
4. Frequently occurs at outside of meander.

Dense Vegetation

1. Poor visibility.
2. May present an impenetrable obstacles.
3. May tanble in running gears, other moving parts.

4. Inhibits cooling.
5. Requires removal or over-riding.
6. Increases motion resistance.
7. May become a slippery surface when wet.
8. Reduces ground contact.
9. Increases soil shear strength.
10. Usually varies with season.
11. Conceals obstacles.
12. Limits light.
13. Can be defoliated.
14. Attracts animals and insects.
15. May provide material for obstacle negotiation.
16. Impairs visibility.
17. May generate obstacles (fallen trees, etc.).
18. Usually associated with poor road nets.
19. High frequency of streams, rivers, bogs.

Urban Areas

1. Usually on firm ground.
2. Usually adjacent to waterway.
3. Traffic is channelized.
4. Visibility restricted in many directions.
5. Barricades easily erected.
6. Disables vehicle blocks traffic.
7. Presence of rubble.
8. Increased threat density.
9. Sharp turns and corners.
10. Narrow defiles.
11. Wheeled vehicles should have advantage due to firm ground.
12. Building characteristics.
    a. Walls
    b. Stairs
    c. Multi-levels
    d. Observation points
    e. Protected firing points

13. Underground communications
    a. Sewers
    b. Subways
    c. Utility tunnels

<u>Rough Terrain</u>

1. Relative to vehicle size.
2. Reduces tractive contact to ground.
3. Damages traction devices.
4. Increases vibration.
5. Reduces operator's capabilities.
6. Reduces control.
7. Threatens operator's health.
8. Increases dynamic forces.
9. Occurs usually on firm ground (soil strength high).

APPENDIX G*

DETAILED TEAM IDEAS

Team No. 1

Members: Rula, Chairman
Hodges
Jones
Hess
Winkworth
S. Ehrlich
Zorowski
Marsh

Basic Mission:

Man/Machine/Environment Interface

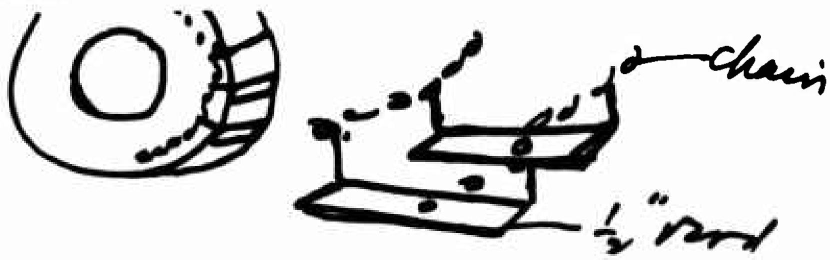
Environments:

Obstacles
River Crossing
Snow

Wheel Concepts

Y Exploit tire technology to determine best tire for snow surfaces.

Y Snow-Use special traction devices for wheeled vehicles in subarctic snow.



*Y Use "Trail Maker" wheels/tracks not as traction devices, not as load-carrying devices, but as "Road Rollers" to prepare the terrain for following vehicles.

Y Put correct tires on vehicles from traction, braking and dynamics standpoint.

Letters preceeding each idea indicate results of later evaluation: N = No; M = Maybe; Y = Yes; Y = "Ten Best"

N Tire Technology - A mobile tire/track system should be so designed and adjustable that the soil shear force angle is never exceeded by the tire/track contact face. The laws of nature and physics do not differentiate between tracks and wheels ut only between the design limitations imposed by the engineer.

*Y Articulated wheel/track system.

Y Snowmobiles with skis for snow and then replace with wheels for hard surface.

Y Wheeled vehicles which can add tires for flotation in soft soil as well as water.

Remote Systems

Y Remote control systems.

M The use of an elevated viewing device (periscope) to see over obstacles. Something like the automakers using a rear view mirror mounted in the roof of a car to obtain an overall vision capability.

Y The possibility of a remote driver's station to allow placing the driver at the optimum shock-resistant point within a vehicle.

N Use of a "mother-child" concept where child is boosted across the obstacle and then the child pulls the mother across.

Air-Ground Systems

N In snow regions, the use of wings to lift vehicles from sinking into ground cover.

M Use of one- or two-man flying platform.

Traction/Flotation Aids

Y Support systems respond to tractive deformation without respect for direction of travel - hence, any steering by skidding, is not just inefficient but wasteful of the support system ductility.

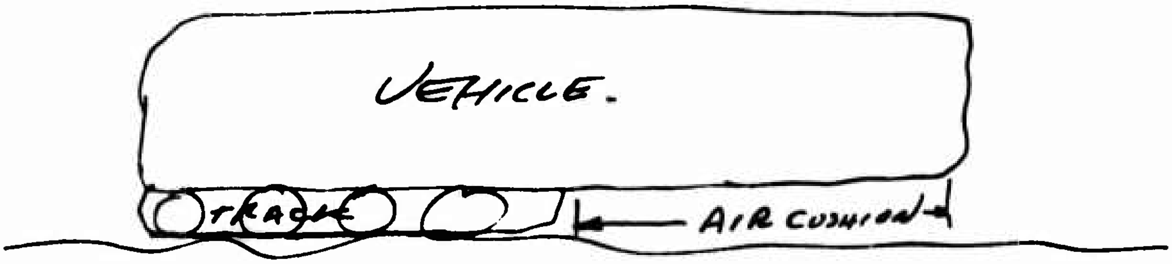
N Build more roads.

N High flotation track pad capable of being replaced with even higher or balloon-type pads to float vehicle.

Y Vehicle passage over terrain should enhance it for second pass whenever power available, tactical purpose of trip and terrain features allow it.

Y Snow, properly compacted, is the most stable road bed. Do not erode stability by penetrating the stabilized first-pass track to such a degree that the "snow bridge or plank" fails.

N Track-propelled air cushion vehicle for snow operation.



N Limit tractive (longitudinal thrust) effect by each load pick-up point to the maximum strength of the soil immediately in front of each point (wheel/track) by tire geometry and loading.

Y Instead of simply thinking "Can this vehicle traverse the course?" would it not be better to think: "Can it somehow improve the course by its passage?" This is somewhat analogous to "drafting" in races.

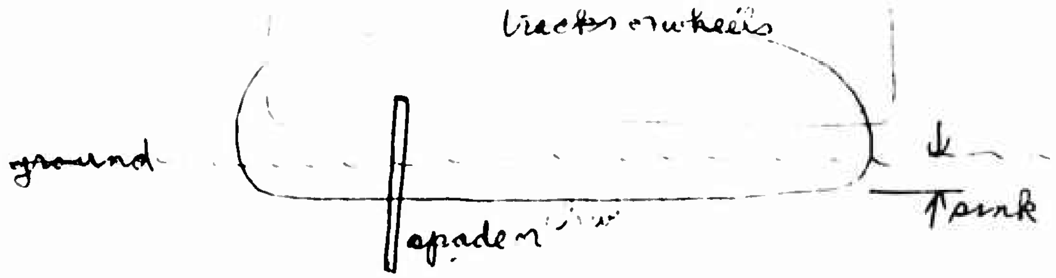
*Y Exploit vehicle momentum in carrying it over obstacles of short duration. The vehicle should be capable of "leaping," much like bike riders in traveling cross country. Leaping, landing, pitching, rolling, etc., cause large amplitude motion of driver relative to controls if controls are fixed to vehicle. Large relative motion implies impact with local surfaces. Both must be avoided. Therefore, do two things: (a) at least crudely servo driver controls by reference to a rough inertial system and (b) when at limit of servo ability cause speed to be reduced. This implies new servo slaved control systems for steering, acceleration, braking, etc.

M Why would snowmobiles not work in the soft flat grasslands that we saw in the movies? (Maybe a different front skid.)

M Provide a means of simply converting the vehicles main power plant output to a "power-take-off-shaft." Then, when terrain is not suitable for the kind of "wheels" his vehicle has, he could drive upon an unpowered (weakly powered) platform having correct "wheels" and use his power to run those wheels.

*Y Two pushers (A & B) alternately push, retract and push using hydraulic cylinders as on construction equipment.

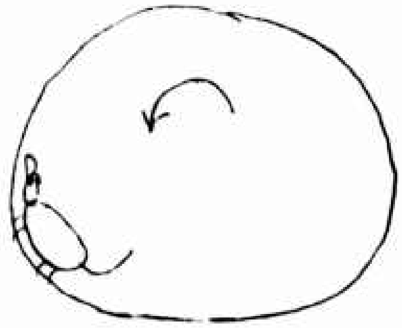
N When bogged down, extend claw into ground, hunch forward, retract, and wipe, move forward inside stomach of vehicle, extend into ground again, hunch forward, etc.



New Vehicle Forms

Y Articulated (controlled) two-piece, all-powered, wide-tracked carrier.

M It might be a good idea to become cylindrical and roll sidewise by climbing the inside of the cylinder (think of a rate in a round cage).

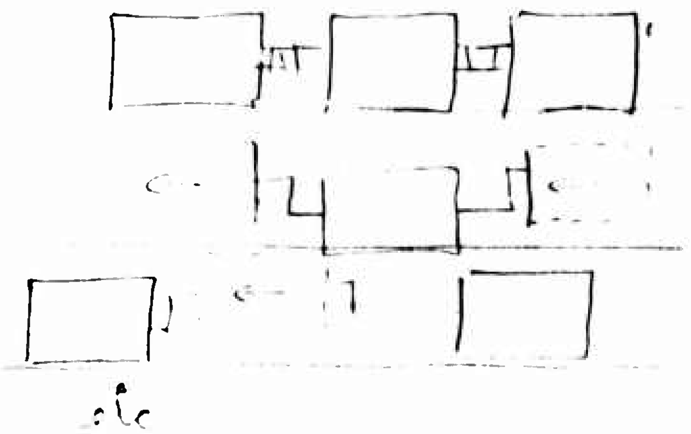


N Why not build a hopper (sort of like a Kangaroo or Pogo Stick) and just plan to hop along on rough terrain and over or onto certain obstacles.

N If South Vietnam were not a friendly country would our tanks not have used dozer blades or simply blasted thru patty dikes and not worried about leaving them intact?

M Special all purpose obstacle-crossing vehicle which leads the way and assists less mobile vehicles. Either airborne or has airborne capability for short periods of time.

N Articulate to provide snake motion, i.e.,



< movement

t = 0	foot < bag	foot < bag
	< bag foot	< bag foot
t = 1	foot < bag	foot < bag
	< bag foot	< bag foot
t = 2	foot < bag	foot < bag
	< bag foot	< bag foot
t = 3	foot < bag	foot < bag
etc.	< bag foot	< bag foot

Flat bags (4, 6 or 8) alternately deflated, moved forward, inflated, etc., so as to move snakewise.

M How about a snowmobile team with more than one pulling a sled for supply purposes or troop transport over snow?

N Snowmobiles (ala commercial) make a great two-man vehicle. How far can they be scaled up?

M For urban areas, a vehicle that could be hinged to avoid obstacles.

M In hard packed snow the use of a vehicle on skis with a leaping action to overcome obstacles.

Y I saw a dog-team race on TV last night. It looked good--how about a snowmobile team with more than one pulling a sled for supply purposes or troop transport over snow?

Y Combine all three reaction mediums--water, air, and ground--to achieve maximum control, velocity, and agility to enter, cross and exit.

N Consider articulated wheel/track-ground pressure aspect/ratio. Articulated sprung/mass-water pressure/aspect ratio. Low freeboard and superstructure-air pressure/aspect ratio.

Y Articulated wheel or tracked vehicles.

Y Provide monocoque cabs to protect operators from mines or small arms, with foam liner to reduce spall and temperature transfer (make him more secure). Modularized and convertible.

Y Provide protection to vital components by compartmentizing and screening for survivability.

Y Develop family of 1/4- to 1-ton payload, limited use, throwaway, wheeled vehicles for operation in difficult environments. Use simple power train system and use appropriate sized wheels and/or traction or flotation aids to overcome terrain demands. Wheels to be made on site using molded urethane. Wearing surface to wheels to be treated with resin. Grousers to be inserted in wheels as terrain demands dictate.

Y Develop snowmobiles into larger thrust-pulling sled-carrying loads.

External Mobility Aids

N To traverse most major obstacles there still seems to be a need to get up in the air or independent of the hard surface. Promote use of suspended cable.

N (For river crossings.) The use of inflatable boats designed to hold vehicles secure.

Y Develop small items to be carried on vehicles for mitigating effect of obstacle.

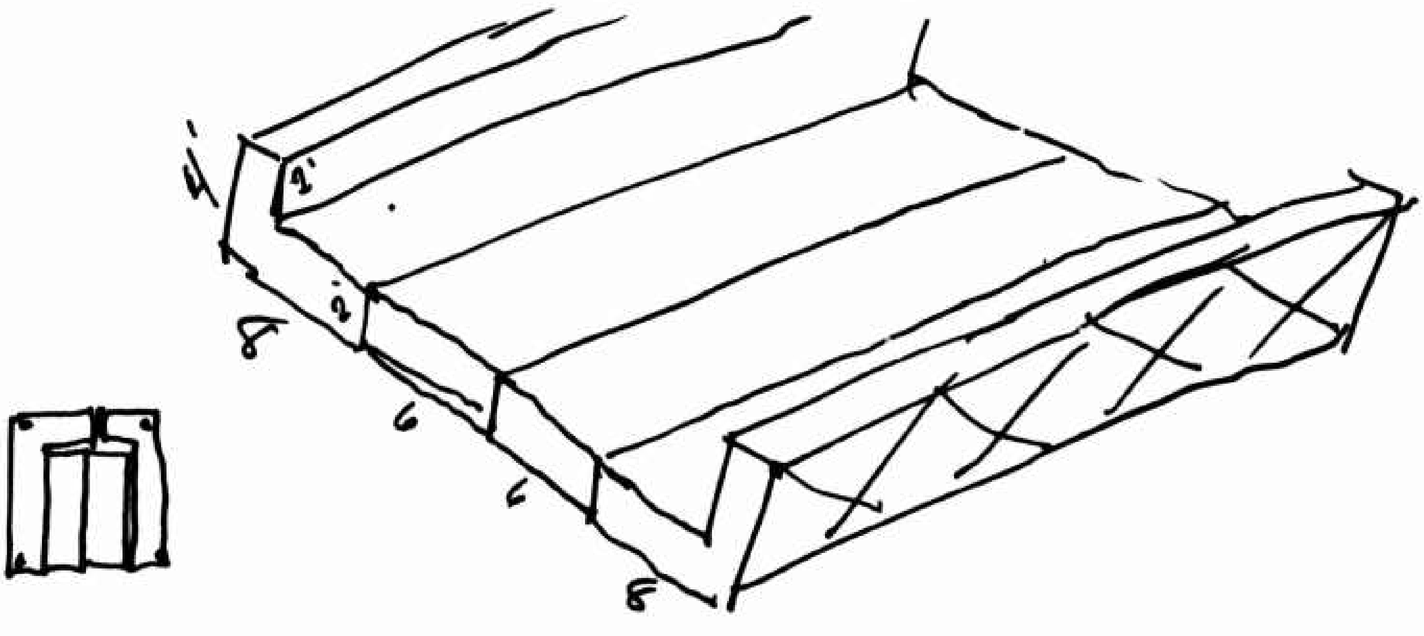
N Mow or weaken dense vegetation with gunfire (as per gunship guns with thousands of rounds per min.) - then run it over.

N An air support vehicle which is caged inside of a ground supported curtain shell which a) holds the air support high enough to clear 2 ft obstacles and b) provides an adaptable curtain to fill in leaks due to ground shape.

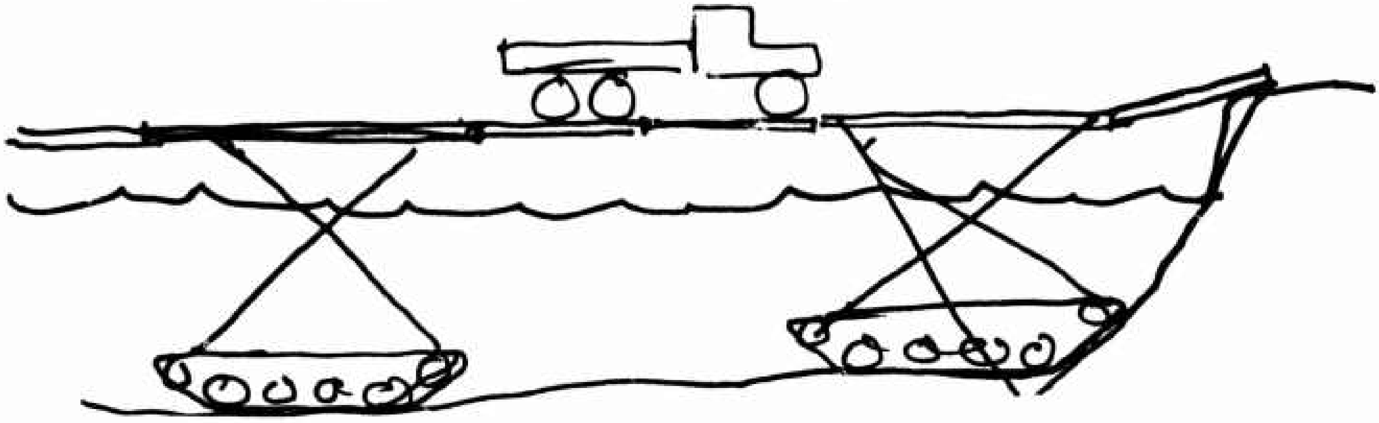
Y Obstacles--snow and shallow rivers. 6" to 32" adjustable ground clearance device. To go under bridges, increase fording capability, go over higher stumps, rocks, obstacles. (Trailing arm-hydraulic piston actuator.)

Y Water Crossings. (Trucks, trailers, etc.) Frame stored erectable water shroud, integral twin hydro-jet units for steer control and power on prime mover only. Train length increases speed.

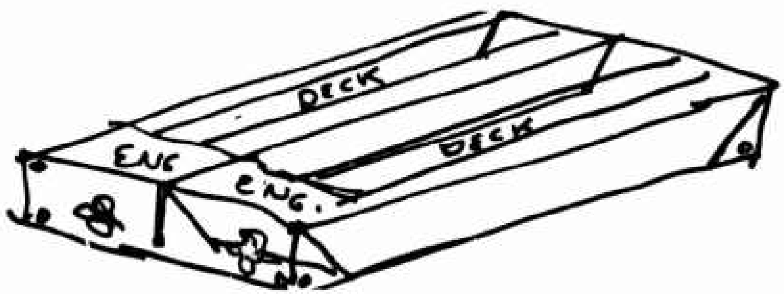
M Modular-container-bridge section. Nesting/folding.



Y River crossings and remote control deep water-scissor bridge units. Extendable platform on sinkable chassis to make bridge.



Y River Crossing. Self-propelled barge to make a ferry or floating bridge.



M Use balloon lift devices to get lead vehicle across river to place anchors and cable for main force.

Y Make vehicles with attachment points for tying on or adding flotation pads or pontoons.

Y Develop drive on ferry sleds for vehicles to float across rivers.

Y Adapt air cushion vehicles for ferrying ground crawling vehicles.

Y Special vehicles used to lift other vehicles over obstacles.

Y New materials used for bridging or modifying obstacles (possibly a foam).

N Mow, bale vegetation into log-like form to lay for roadbase or fortification and to clear fire areas.

Y If you float, why not fire a cable anchor across and winch across just as a simple farmer's ferry does.

Y Recall old-time railroad building equipment which carried rails, laid them while moving on them. How about a special-purpose grid layer which simply unloads grids ahead of itself while moving forward on them.

Y Use explosives to decrease magnitude of river bank slopes.

*Y Develop in each vehicle category the capability of modifying obstacle with specialized hand tools driven by a power takeoff, electrical or pneumatic. Also tool capable of limited lifting or dozing capabilities. Provide alternate systems to increase get home reliability and survivability.

*Y Vehicles should have a 'last effort' capability such as an autolaunch of an anchor.

Y Slippery banks could be improved by the dumping of jacks (think of girls' game) onto the bank--like sand box on locomotives or cross-country trucks (commerical).

Y An air support (air cushion) cargo device which is towed by a ground contact vehicle.

M Special all-purpose obstacle-crossing vehicle which leads the way and assists less mobile vehicles. Either airborne or has airborne capability for short periods of time.

Y Develop aerosol material for hardening snow.

Power Sources

Y Develop powerplants that are virtually free of pollutants and require a minimum of fuel.

*Y Develop electrical transmission for all wheel drive/tracked multi-engine prime mover towing a train of powered tracked dollies and semi-trailers (tracked).

Y Develop practical electrical power train systems.

Modular Design

Y Use modular plug in replacement of critical components. For quick repair.

Driver Aids

N Provide automatic pilot type drive with immediate driver override base on adjustable threshholds.

M Man is not adequately supported. Dynamic environment too rough at speed. Vision poor. Man is connected to machine in too many places. Man has too many joint operations to carry out. Man has to predict performance rather than choose route on simple parameters. One man used to drive; maybe two is better.

Y Singularize vehicle control systems that is, make the vehicle controllable only by the feet (thus leaving the hands free to do other tasks) or by the hands (thus leaving the feet free).

Y Provide driver training courses which would include how to "read" the terrain for mobility purposes.

Y Air-conditioning for hot climates; heating for cold climates.

Y Have the seat of the vehicle adjustable to make driver more efficient and more comfortable.

N Computer system to help driver use the right techniques for his specific problem.

Y Driver ejection device for operations in water.

*Y Develop driver simulator training devices.

Y Reduce displays through automation (automatic switching gear).

Y Provide alternate systems to increase get-home reliability and survivability.

N Provide a comfortable vehicle environment, i.e., noise, temperature, vibration.

Y A sensing device for all parts of vehicle to see problems arising.

Y Isolate occupants from noise, shock, vibration, and fumes (location).

Y Provide life support console to reduce his obligations and non-operator functions.

Y Route selection, radially, from present vehicle position should extend, tactically, for a few hundred yards. Route selection should provide information on probability of negotiation and estimated speed possible. Vision from vehicle may not be adequate to see over hills through brush around corners or, in dust, very far. Provide intervehicle communication between scout vehicles and main vehicle to other vehicles; this should consist of a plan-position-indicator, speed made good, and vehicle code. The driver would have ability to "learn from" his colleagues at extended (up to 500 yard) range. Develop simplified vehicle controls.

Y Panoramic terrain display.

N Isolate crew from vehicle and environment; provide separate life control system, but permit complete body freedom. Operator is connected to machine in too many places.

Y Develop devices to moderate terrain impact.

*Y Stabilize "sprung" mass only.

Y Improve suspension system for absorbing energy inputs--use variable spring rates.

Y Increase wheel or track travel.

Y Provide commonality between vehicles in operator station and other crew areas.

Y Advance Terrain-Sensor System for controlling vehicle.

N Provide integrated automatic controls.

Y Simplified control systems.

Y Provide alternate vehicle control points, depending on mission or situation. Singularize vehicle control systems, that is, make the vehicle controllable only by the feet (thus leaving the hands free to do other tasks) or by the hands (thus leaving the feet free).

Y Improve train/trail maneuverability.

Y Divide vehicle function display observations among operating personnel such as is currently done in aircraft.

Y Fiberoptics information transmission.

M Use of remote visibility sensors; remote from vehicle (possibly airplanes) controlled by operator of vehicle.

Y A simple may (or better, local cheap and dirty air photo) board with approximate local position indicator which will inform driver of best driving tactics; i.e., speed up to jump, steer to the right around a terrain feature, etc. A navigator in simplest form can move the indicator and give verbal advice (and replace maps). Command planning would be possible (experience of yours and others from past trips can be noted, etc.)

Y Feedback of vehicle response to modify or change response characteristics; modify vehicle response based on response feedback.

Y Provide most level ride platform possible in the geometry available.

*Y The need to develop more shock-resistant men. Possibly encase them in a fluid--like they do cameras for taking movies from helicopters, or the compass encased in oil or like a person's eyeballs. Possibly a "G" suit, like aircraft pilots to react to rapid changes in vibration. Suspend driver in a harness so that his body is protected against hitting the seat and causing stress on spine.

M Air cushion the vehicle with wheels for control of turning, braking, and speed. One basic problem has been that the operator drives by the seat of his pants or is a victim of the terrain. He therefore needs higher rate suspension systems commensurate with his required operation.

*Y Enhance driver vision, day or night.

Non-Hardware Ideas

Y Avoid or maintain constant contact aspect/ratio regardless of attitude.

Y River Crossing: For it, don't float it.

Y Develop systems for sensing, interpreting, and varying vehicle characteristic automatically such that obstacle performance (speed of crossing) is increased.

N The laws of nature and physics do not differentiate between tracks and wheels. But only between the design limitations imposed by the engineer. Develop software to evaluate the terrain for mobility purposes in the theater of operations.

- Y Develop techniques for locating potential river crossing sites.
- Y Assemble current obstacle technology in usable form.
- *Y Develop a computer compatible terrain factor measuring and recording system for field use.
- Y Conduct terrain studies to establish magnitude of obstacle problem through knowledge of frequency of occurrence and areal occupancy information.

Team No. 2

Members: Carr, Chairman
Markow
Boudinot
Bekker
Fadum
Banks
Ziem
Bradshaw

Basic Mission:

Vehicle Morphology

Environments:

Soft Soil
Slippery Surfaces
Steep Slopes

Wheel Concepts

*Y A "condual" (multiple concentric pneumatic chambers), radian and other tire/wheel designs.

*Y Reduced vulnerability tires by multiple structure, castable polyurethane, ball filled, non-pneumatic, etc.

M Expanding multiple wheel disks to use as viscous shear disks for fluid mud propulsion.

**Y Wheel-track convertible logistical vehicles (based on new power train/steering technology).

M Air cushion with wheels for control of turning, braking and speed.

M Wheel-pump device where the tires rotate 90°, to get better thrust.

N Provide warning system which would be activated when tire or track slip exceeds the safe maximum, predetermined for each soil type.

N Provide automatic tire inflation and torque control which would adjust the tire and thrust pressure to soil conditions for optimum traction.

**Y Multiple soft roller vehicle with air film or magnetic suspension between rollers and body and propelled by a gas generator or linear electrical motor driving magnetic tape or metallic wire reinforced bags.

Remote Systems

M Use balloons as complement to combat vehicle--as observation platform.

N A remote driver's station to allow placing the driver at the optimum shock resistant point within a vehicle.

N Drone-carrying TV to aid in route selection.

**Y Remote control by simulation-telemetry to operator.

*Y Mother-daughter concept: remote controlled vehicles to provide observation, mine detection, electronic countermeasures; like aircraft for a Navy task force; or drones to a manned bomber force.

Air/Ground Systems

N Use flying platforms.

N RAM Air wing--transient contact vehicle-part wheel, part aero support.

**Y Combat vehicles which can be transported by U.S. Heavy Lift Helicopters (18 tons).

Traction/Floatation Aids

*Y GEM assisted heavy armored vehicles to reduce one-pass 20-30 VCI trafficability capability to 7-10 VCI.

M Use high frequency vibratory skid to reduce surface friction--propeller/fan/jet for thrust. Utilize existing vibration of propulsion system, use this energy and to apply to skid.

*Y Suction cups or polyurethane tires and track pads impregnated with metallic grit or optimized agressive grousers and treads for high traction on slippery surfaces.

M Equip trailers with drive system that can feed off of rear differential and provide assist when necessary.

M Use powered trailers like the British do.

**Y Flexible tracks which would provide longer life and weight saving through the distribution of peak loads.

**Y Track suspension supported by ski-type, sliding, low friction surfaces (instead of road wheels) - air, fluid, solid lubricant, magnetic.

N Cycloidal locomotion (like helicopter with low disk loading); exploit dynamic strength of soil.

N Provide ski-type track suspension, in addition to the regular road wheels, which could be lowered to support the vehicle in case of extremely soft ground with purpose of reducing the peak loads incurred in track road wheel systems.

N Use gas turbine exhaust for the partial lifting of the vehicle, in critical soil conditions by providing simple collapsible air cushions.

M Fold down inflatable air cushion lifting device kit to reduce ground pressure.

N Hot ski in saturated soils (use engine exhaust) flashes water to provide a steam interface or dries out soil for better trafficability.

N Glue emitting traction aid--for slippery surface (house-fly).

M Use unidirectional thrust surface on vibrating skid--(like vibrating conveyor belts).

Y Deep penetration, aggressive treads for tires and tracks.

Y Variable geometry tracks: low pressure for soft soils, high pressure for slippery surfaces.

New Vehicle Forms

N Development of wheel - screw vehicle.

N Development of the track screw combination.

**Y Develop an advanced air-roll vehicle.

N Tri-track system.

**Y Air cushion with fore and aft thin knife-like wheel disks to provide lateral restraint - travel on slopes would now be possible.

N Flexible accordian, snake-like propulsion vehicle.

M Long, very minimum profile, articulated vehicle--bridging on demand (pitch control)--with centerline wheel/track suspension; stabilized by momentum, wheels, gyros or pulse jets.

**Y Articulated tracked vehicles.

M Make a very long articulated vehicle form by entrainment.

Y Run tracks in opposite directions to generate trench for vehicle protection.

N Stabilization system for center-supported vehicles.

N Go fast - use high energy thruster, planing hull geometry, high slip wheel propulsion for high speed thrust.

N Build vehicle in shape of two concentric spheres--inner one stabilized, outer one rotating for locomotion.

M Use honeycomb structure and carry fuel within voids of honeycomb.

M Articulated armored vehicles with an armored joint integrated with vehicle body instead of being attached to it.

M Dynamically coupled vehicle train--rigid for impulsive loads; articulated for normal motions--pneumatic or hydraulic coupling device.

M High speed, very weak soil vehicles--exploit inertial soil effects of saturated soils. Use external thrust (not wheels); plane on soil much as a planing boat.

M Pillow drive.

M GEM sleds pulled by tracked or air-roll vehicle.

**Y Provide protection only for vital components by compartmentalizing.

*Y Pathfinder vehicle with very high pressure water jets for knocking down steep banks in order for it and following vehicle to exit from a river.

M Totally inflatable vehicle structure--provides vehicle accommodation of surface geometry--small stowed non-operating volume.

M Self-entrenching articulated vehicle--opposed, driven tracks dig a hole for low profile during stationary combat.

N Articulated air cushion vehicle.

N Use worm-likemotion.

Y Light, spaced armor for travel; fill spaces with soil for combat protection.

<u>External Aids</u>

N Use four small high thrust rockets burning same fuel as main propulsion system to reduce ground pressure - Could also serve as a dash propulsion.

N Hang vehicle from a kite in the jet stream.

N Use anti-gravity device.

N Establish soil anchor on hill top - all operational vehicles climb the cable.

N Carry "tire chain" liquid to be sprayed over slippery surface when needed.

N Fill trail with path of water and float on it.

N Provide in front of the vehicle some sort of spreaders and/or sprayers, which would cover the slope with anti-slip substances.

N Use balloons as lifters--inflated from hot exhaust gases--when stuck in mud.

Y Provide bulldozer blade or backhoe to facilitate getting up banks.

N Fire grabbling hooks attached to a winch or capstan to aid obstacle negotiation.

*Y High-impulse JATO thrusters - primarily for water exiting.

N Surface hardener fluid.

Power Sources

M Electronically stimulated (commanded) animals--animal robots.

N Use dog sleds.

M Use centrifugal force produced by controlled phases set of rotating eccentric masses to provide boost in lift and thrust for obstacle clearance.

M Vehicle that lives off the land; makes its own fuel.

M Compound engines.

M Turbine tracks--gases--instead of a gear box to directly drive the track.

M Stream jet propulsion--use indigenous water to provide quick scoot acceleration.

N Use explosive charges behind a big iron plate to get propulsive forces.

*Y Air over water impulse thruster to aid water exiting.

*Y Simple auxiliary propeller swimming propulsion system as used on the German WWII jeep.

M Water dump into fan propulsion to get short acceleration capability.

Y Lightweight, wisker construction, high speed, high momentum flywheel for short bursts of high power to help in negotiating obstacles, exiting from rivers, or getting over hump power requirements for amphibians.

M Pulse jet water device--simple, lightweight, no drive train-water propulsion system.

**Y Alternate fuels and power plants to replace hydrocarbon fuels.

N Nuclear ground propulsion.

N Non air-breathing propulsion system for burrowing or submerged vehicle.

M Make non-flammable fuels.

N Electromagnetic propulsion and suspension.

**Y Microwave power transmission to vehicles from primary power source be investigated.

Modular Concepts

**Y Component modular structured vehicles.

**Y Advanced state-of-the-art electric powered hub. Exploit the evolving super magnetic materials and micrologic electronics.

Driver Aids

M Active suspension systems.

M Provide a warning system which would be activated in case of approaching imminent overturning of the vehicle.

Y Automatic control of speed and movement for individual vehicles in a convoy which can be remotely controlled or preprogrammed.

N Elevated TV for improved view.

Y Large stroke, active or adaptive suspension system.

N Provide the driver or navigator with terrain sensing devices to read the terrain at an appropriate distance in front of the vehicle.

*Y Develop driver simulator training devices.

Y Provide driver training courses which would include how to "read" the terrain for mobility purposes.

*Y Provide precision navigation readouts for position location.

Y Liquid cushion suspension: metal particles suspended in solution and rigidity controlled by magnetic field.

N Automatically adjustable damping rate, controlled by ride severity measurement (automatic tuning away from resonance range).

N Air over hydraulic suspension system whose characteristic is controlled by the dynamic wheel (road wheel) load variation.

Non-Hardware Ideas

M Transpiration cooling to reduce infrared signature.

*Y Use of COR-TEN steel and/or surface coatings to reduce radar profile.

Team No. 3

Members: Dugoff, Chairman
Clark
Taylor
Schuring
Calder
R. Ehrlich

Basic Mission:

Traction Systems

Environments:

Dense Vegetation
Urban Areas
Terrain Roughness

Wheel Concepts

M A quick response inflatable loop (tire) which will increase bearing surface as a sensor indicates need. (A pneumatic wheel with remotely controllable shape).

M A tire (pneumatic or other) with strong enough structure to replace the track.

*Y Make wheels so additional wheels can be easily attached (bolted) together to form duals, triples, etc.

Y Spherical wheels (like furniture casters) for omni-directional operation.

Y Cheap, expendable, light, track-over-wheel device, used and discarded as necessary (possibly of mylar) or nylon tape)

M Paddle wheel for propulsion in both land and water.

N Spiked wheels (no inflated rubber).

M Extremely large tires (or wheels) - 10 ft or larger - to change the wheel/terrain scale.

N Profiled tires which present a small surface for highways, but a large one for soft soils.

Y Control to put spikes out on wheels or tracks for ice operations.

M Big-bag vehicle for crossing obstacles or rough ground.

- M Attachable, lightweight cage to bolt onto wheel.
- Y Wheels which change shape as they turn to present a large contact area to ground.
- M Central inflation systems.
- N Extremely low pressure tires.

Remote Systems

- N Remote control (satellite)? for air cushion vehicles.
- Y Remote controlled recon mini-vehicle.
- Y Inexpensive, remote-controlled combat vehicle.

Air/Ground System

- N Aerial terrain routing, use aircraft to detect or sense best route (similar to oil exploration techniques).
- Y Use the mass (weight) of the soil beneath vehicle to aid traction.
- Y Grouser to reach down to firm ground and then come up straight.
- N Liquid track.
- *Y More direct engagement of energy source to terrain (less dependence upon friction forces in soil - traction device interface (Operation Red Sod).
- M For soft ground passage, a quasi-flotation system through a tire or other device with adjustable orifices to approach an air cushion device (air bearing).
- Y Use reaction forces to assist traction by throwing back soil, mud, etc.
- N Electrostatic repulsion system to reduce ground pressure.
- M A traction system which generates an extremely large interface whose size can be controlled by terrain or soil sensors, according to need.
- Y A traction force, generated and executed outside the vehicle-ground interface so as to divorce the traction generating mechanism from the vehicle supporting function.
- M Use combustion gases directly to remove soft soil or obstacles in front of vehicle (Red Sod).
- M A responsive track system with grousers that vary according to the soil surface, working at front or rear (or both), which will present a greater area normal to the appropriate direction, as it is needed.
- M Track w/lugs engaged in inverse proportion to speed - work in combination w/wheels. High-speed hard surface - all wheels. Low speed - soft surface - all track. Continuous, variation between the both kinds.

N Variable aspect track-width which varies with speed (by centrifugal action)?

M Adjustable track axles.

*Y Technique for obtaining thrust force from obstacles (rocks, trees).

M Fluid filled bag suspension, bottom surface covered with ball bearings.

M Floor Scrubber analogy: fluid bed laid down and picked up behind vehicle.

Y Better (lighter) skirt materials for ACV.

Y Development of materials which adhere to "slippery" surfaces.

N Larger traction components would make terrain "look" smoother.

New Vehicle Forms

Y Inching vehicle - articulated vehicle which selectively moves one part at a time forward by selective expanding and contracting the connecting joints.

N Inchworm traction.

M Traction-like worms (accordion like traction): cylinder which can expand and contract.

M Design vehicle so that another vehicle could surmount it easily for: (1) mobile ramp, (2) easily bypassed when disabled in defiles.

M Combustion-gas-cushion vehicle.

M Gyro vertical balance to allow vertically unstable configuration to remain upright in order to form motorcycle trains.

N Armored Cherry Picker for getting at upper floors of buildings.

M Armored one-man vehicle.

Y Motorcycles, motor scooters, trail bikes.

M Climbing vehicle with force-feedback arms (climbs up outsides of buildings).

N Stair - climbing vehicle.

Y Motorcycle train with stabilizing mechanism such as outriggers for stationary mode.

M Bellyless vehicle.

M Low-cost, throw-away, lightly-armored, recoilless-armed combat vehicle, which can be adapted from present commercial production to flood the battlefield in time of war.

Y Re-think articulated vehicle concept for tanks and APCS.

M Skiing-walking machine (use skiing motion for propulsion).

Y Monkey machine (swing from tree to tree).

Y Vehicle which obtains propulsive forces by grabbing vegetation.

Y Multi-unit articulated body (matrix of hinges?)

Y Vehicle which can enter and exit thru manhole and operate in sewers for urban warfare.

Y Jumping vehicle (a la soil compactor) as a pogo-stick-type vehicle.

Y Multiple forms of traction devices on same vehicle (e.g., ACV with rubber tires).

M Build vehicle in shape of circle or elipse with gyro stabilizer.

Y Lengthen vehicle (by entraining) to smooth ride.

Y Air cushion vehicle technology which will allow accurate steering.

N Underground burrowing (as a ground hog).

N Liquid cushion (vs. air cushion).

N Push thru the earth and move it on (as an Archimedes screw).

<u>External Mobility Aids</u>

Y Rocket for obstacle hopping.

N Flood ruts, then float in them.

*Y A highly mobile pioneer vehicle equipped with many auxiliary mobility aids (winches, dozer blade, front-end loader, etc.) to clear way for following vehicles and assist their travel.

Y Capstan auxiliary drive for tracked vehicles (but this time do it right: make the capstan diameter <u>larger</u> than the drive sprockets).

Y Improved soil anchors for self-winching.

N Satellite control to lift, etc. (like a puppet on a string).

N Development of Compact High-Thrust rockets.

Y Development of some fluid which could be sprayed on soft or slippery ground, to make it harder or more frictional.

M Front-end loader mounted on vehicle to: remove rubber, knock down walls, lift objects to upper floors.

N Man-amplifier building-knocker-downer.

M Mobile ramp (vehicle which is also a ramp).

N Jet exhaust reaction for propulsion.

N Freeze dry terrain by flash of vacuum.

N A lift device (balloon) which can be quickly inflated to reduce surface pressure as needed.

N A moving lake to float on--possible in marshes.

N Flood a path, then use floating vehicles.

Y Self-launching grapling hook or soil anchors.

N Ground leveler (bulldozer blade) in front of vehicle.

M Equip vehicle with chain saw in front to clear out vegetation.

M Laser obstacle disintegrator.

N Capstan on vehicle to help propel across river by cable assist.

M Cable-assisted operations.

Y Active missile-defeating device for less weighty armour (Re-do dash-dot system in light of new computer and sensor technology).

Y Big bag - place vehicle or people in large bag.

M Tree-farmer equipped vehicle to clear out forest, lay ramps with felled trees, etc.

M Movable shield to armor part needed, thus reduce total required armor.

N Cable-carrying balloon towed by small ground vehicle through dense vegetation.

M Separate water from soil by vacuum, polarization, heat application, pressure.

Y Rapidly hardening foam to spread out vehicle bearing pressure.

M Fast growing vegetation whose root structure strengthens soil and is not degraded by traffic.

N A lift for disabled vehicles so others can go under or around.

Y One-man rocket (or turbine or air screw) assisted propulsion system (non-flying) to aid in the propulsion of a person or skis, roller skates, bicycle, air bearing.

M Bow up bags w/exhaust for flotation.

Y Armor shell (self-supporting) to be pushed along by a vehicle inside.

Power Sources

M Use fuel combustion process directly to move soil and obtain thrust.

M Use energy from fuel directly without going thru an engine to achieve thrust and control in an ACV.

*Y Use soil as the piston and fuel as propulsor, cylinder in soil.

Y Flywheel to store energy in an idling vehicle for high acceleration starts.

M Multiple natural power sources (sun, wind, rain, etc.) to run electric motor, charge battery, etc.)

M Self-winding or pendulum drive for flywheel power in rough terrain.

M Material thrust motor using slurry, mud or snow.

Driver Aids

- Y Means of identifying the stronger parts of the soil to obtain best footing available.
- Y Computer-assisted dynamic suspension system to sense terrain roughness and adjust suspension accordingly.
- M Use sonic techniques (velocity) to determine soil characteristics.
- Y Use nuclear radiation to determine soil characteristics.
- Y Automatic controls to optimize slip, prevent spinout.
- Y Feasible control systems for walking vehicle (as per nature).
- Y Electronic sensors to identify firm or smooth terrain.

Non-Hardware Ideas

- Y Set-up a small team to review past concepts (such as presented by Nuttall) to determine reasons for discard and determine if they are worth pursuing again.
- *Y Development of traction mechanics capable of using soil strength criterion to design vehicles more accurately.

Team No. 4

Team Members: Latson, Chairman
Remus
Panger
Braun
Gregory
Nadler
Barrett

Basic Mission:

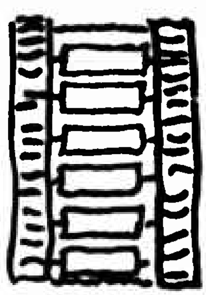
Propulsion System

Environments:

Obstacles
Soft Soils
Dense Vegetation

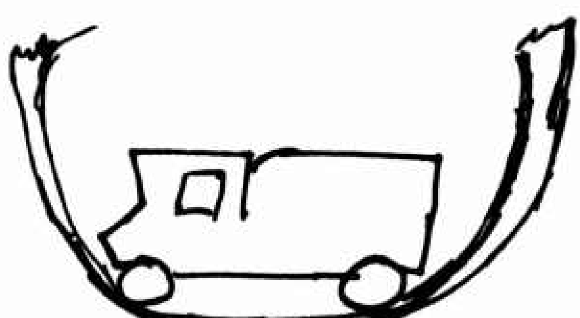
<u>Wheel Concepts</u>

M Quickly inflated rollers on the belly of vehicle to help it roll over soft ground.



View of Bottom of Tracked Vehicle

N Large hollow wheel with carrier inside.



M Variable Geometry Tire

N Develop a high flotation, high speed combination tire.

M Giant steamroller (override vegetation).

M Front wheel drive - all wheel drive.

M Power application to omnidirectional wheels - directionally tractively controllable.

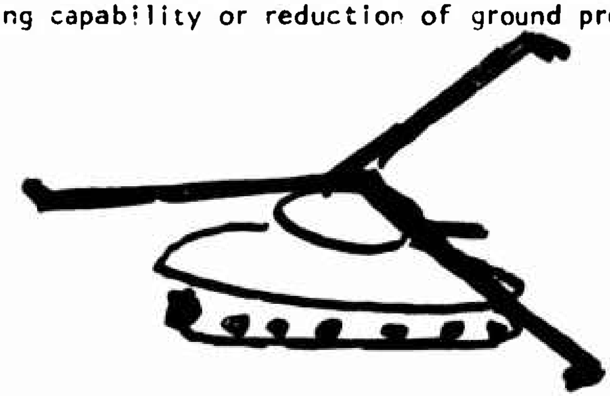
Remote Systems

M Develop remotely operated combat vehicle propulsion systems to eliminate or reduce the human factor limitation on maximum speed over rough terrain for tanks and other combat vehicles.

Air/Ground Systems

N Eliminate all vehicles which do not have flying capability.

M Tip driven folding rotors up for normal road travel for obstacle jumping capability or reduction of ground pressure.



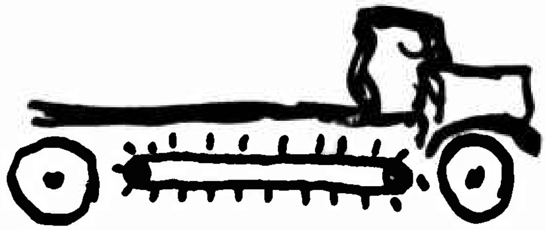
Traction/Flotation Aids

M Fold down large skid pads on each side of the vehicle to give more flotation.

*Y Multi-armed (legged) walking vehicle that can roll, grab, walk on several sides (faces).

Y Use a system to grab obstacle and pull/hoist vehicle over it.

M Use a "Tucker Snow Cat" type spaced link system on the belly pan of a vehicle.



Y Auxiliary propulsion bits such as propellers, water jets, outrigger wheels, powered dollies, etc.

N Extra flotation devices to help heavy vehicles transverse streets which have sewers-conduits beneath.

New Vehicle Forms

N Locked track system. Vehicle could then climb up this system. We must control the summit.

N Swimmer with burrowing capability to bit into and burrow through river banks.

N Vehicles that change shape to squeeze through or slither around obstacles.

M Self-loading and unloading, capability would decrease turn-around time, increase availability, hence, effectively increase mobility.

M Power-joint articulated, inching vehicle.

M Large self-cleaning, single screw machine with carrier internal to screw.

N Leap-over-obstacle capability.

Y Pillow drive (proprietary).

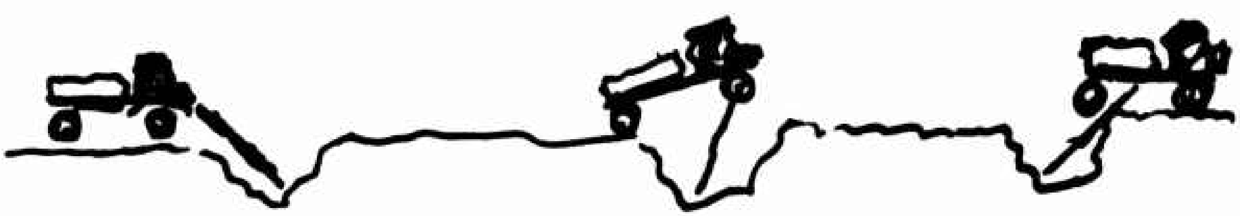
M Burrowing vehicle.

N Burrowing to assist in water exiting.

M "Walking Machine."

External Mobility Aids

M Use a pole vault device to get the vehicle over obstacle.



M Mount a telescoping crane on the vehicle to move large rocks - fallen trees, etc., out of the way.

M Foamable plastics to fill holes or ramp vertical obstacles.

M Cylinder attachments to push vehicle out of temporary immobility.

Y Anchor launcher tied to winch to assist temporarily immobilized vehicle.

M Use power plant to operate laser cutting beam.

M Use thrusters to burn, knock down, or clear vegetation.

M Large snippers such as gardener's lopping shears that cut off the tree near ground. (Helicopters already do this to cut cables.)

M Use of Red Sod Technique to cut trees.

M Giant center-bladed Rome plow vehicle.

M Front-mounted vibratory shear near sonic range to cut large trees in frozen areas.

M Powerful laser to cut down larger trees.

M High frequency impacter to remove rubble and other obstacles.

N Portable brick-rubble ingester (rock crusher) to ingest rubber and spew out gravel.

M Auxiliary thrusters for use at peak traction or control requirements.

M Throw cables across chasms to transport vehicle to other side.

M Distribute a newly developed instant soil hardner in front of vehicle.

Y Water jet to wash down river banks (Forced erosion to cut ramp.)

M Use thrusters to raise vehicle over or partly over the obstacle.

M Use thrusters to reduce vehicle weight and sinkage.

<u>Power Sources</u>

Y Improved automatic transmissions.

Y Optimized power system.

*Y Propulsion systems that are integrated into the device providing tractive effort.

Y Develop engine with proper torque-rpm characteristics - eliminate transmission, rear end gears.

Y Develop variable torque converters so that engine can run at constant speed.

M Infinitely variable drive:

a. hydraulic wheel
b. hydro mechanical
c. hydro electrical
d. turbo mechanical

N Develop way to use heat from solar/nuclear power to dry soil if wet.

M Self-contained oxygen for engine and crew for convert operations. Inertial navigation for driver orientation underwater operations. Large, lightweight, knockdown ACV rafts hauled across by winches (could be inflatable).

*Y Substitute fuels - hydrogen, ammonia, etc.

N Animal power.

N Ingest slippery material (mud) and force out for additional thrust.

N Turbine exhaust blasting on ground in front of driving wheels to dry out ground.

Y Use the propulsion system as a part of the weapon system. For example, to provide a large burst of controlled power for a weapon.

M Quick changeover (3 to 5 minutes) to non-air breathing propulsion system for brief submerged operation (5 to 20 minutes) for crossing rivers, beach landings, etc.

*Y Develop means to quickly change-over our existing engines from conventional fuels; gasoline, diesel fuel (or JP4) to synthetic fuels (LNG or Methane) to meet a possible Mid-East oil cut-off energy crises - especially for European Theatre operations. Decrease in performance or combat survivability to be minimized.

M Use exhaust directly to achieve desired effect rather than convert to rotary motion, e.g., to inflate an air cushion skirt for expedient, short-term flotation.

*Y Vapor cycle engines:

a. steam
b. Rankine
c. Stirling

N Use of plant growth energy to power vehicle.

N Self-healing propulsion systems that sense oncoming failure and compensate before failure becomes catastrophic.

M Develop low cost, short life combat vehicles and propulsion systems. Combat life is measured in minutes. Therefore, why develop 6000 hour traction systems for cross-country vehicles?

Y Have exhaust of engine to feed into Air Cushion vehicle skirt. Loss in performance due to back pressure should be more than compensated by added gas volume from combustion products and heat.

M Central system to store/regenerate wheel jounce, weapon recoil, vehicle braking, etc., for supply of peak power at a later time.

*Y Use of normally wasted products of energy generation for other uses; for example, air conditioning, electric generation, thermoelectric conversion, turbine generator.

*Y Electric drive:

a. electric wheel
b. hybrid

M Linear induction motor.

M Increased use of turbine power.

Y Magnetic suspension and drive.

N Propulsion systems that don't have to idle when not providing power.

*Y Reduce total power or propulsion signature noise, IR, gases, light.

*Y Stored energy for peak power requirements:

a. Flywheel
b. Battery
c. Spring
d. Accumulator
e. Crew

Y Transmission of energy from a central point to vehicles in the field by wireless means.

Y Solar energy propulsion system.

M People power for peak demand requirements.

Modular Design

M Multiply linked propulsion systems. Items that can be added or removed that have powered traction.

Driver Aids

Y Mobility failure sensing feature, to provide override and optimum drive parameters.

N Elimination of instrumentation. Do away with oil pressure gage, coolant temperature, engine RPM, tail pipe temperature.

N Automatic engine interrogation and evaluation portable diagnostic system.

M Man-vehicle interface - training devices that teach driver how much driving stress they can take.

Y Driver training technology must be improved. Driver is usually the limiting factor.

N TV or periscope in snorkel for bottom crawling vehicles in deep fording.

Team No. 5

Team Members: Patek, Chairman
Hamilton
Czako
Spanski
Douglas
Duane
Bronner

Basic Mission:

Suspension Systems

Environments:

River Crossing
Slippery Surfaces
Urban Areas

Wheel Concepts

Y Fibreglass parabolic wheel.

N Combine paddle wheel propulsion with conventional wheels.

Remote Systems

M Deceiver vehicle to clear mines.

Y Remote control vehicle eliminates driver limit on mobility.

Air/Ground Systems

N Auxiliary helicopter kit for river or large obstacle crossing capability.

N Individual means of transportation for the soldier, i.e., flying belts.

Traction/Flotation Aids

N Slide (make it slippery) vehicles around tight city corners.

Y Numerous separate rubber bands to act as tracks (power belts).

M Non-mechanical drive in track vehicles to reduce noise.

Y Use "Voth=Schneider" (cycloidal) propeller in bottom of vehicle.

Y Track pads or tires that have variable friction-ground pressure capabilities either by sweating sticking fluid or changing shape and foot print:

a) cone type wheel
b) foam or liquid filled
c) liquid tire chain
d) central tire inflation
e) spiked track pads
f) pneumatic track pads
g) discardable track pad width extensions
h) flair out footing
i) brush-like wheels

Y Band-type track for heavy GVW (60,000 lb to 120,000 lb) vehicles to reduce vibrational power losses.

M Walking vehicle with suction cups to overcome slipperiness.

New Vehicle Forms

M Have moving ballistic surfaces to improve or change penetration capability.

N Obtain ballistic projection by pillow or marshmallow effect (absorb shock of projectile). Allows weight reduction.

Y Encapsulate driver and or cargo in positionally stabilized shock insulated compartment.

Y Pitch control for crossing bombcraters in streets.

N Vehicle capable of turning on its side and driving forward (thru narrow openings).

Y Articulated Combat Vehicles overcome the inherent length-to-width ratio problem and allows longer narrower vehicle.

M Eliminate turret, gun positioning through variable height suspension.

M Jet Assist/Hybrid Vehicle.

M Marsh Screw/wheel/track hybrid vehicle.

Y Lightweight air cushion wheel or track vehicle hybrid.

M Floor of hull becomes two large walking feet to assist in soft soil.

M Suspension capable of automatically changing its chassis position to affect weight distribution and CG transfer capability.

Y Variable width vehicle. Possible elastic side walls external to armor for storing fluid vehicle requirements. Allows squeeze through tight spaces.

M Wheels positionable fore and aft to shorten or lengthen wheel base.

M Develop 2 or 3-wheel type vehicle suspension.

N Boat shaped body to improve water speed.

M Hybrid vehicle using archimedes screw for water propulsion and exiting of water.

Y Special-purpose, cheap, lightweight vehicles.

N Crab steer capability.

M Walking device - second generation - force feedback controlled by human operator.

External Mobility Aids

N Use temporary interlocking aircraft landing mats on river banks.

Y Spray bank with tractive or hardening substance.

Y C carpet-like device which would cover weak soil areas.

N Quickly detach cargo to lighten vehicle and drag over on a cable under water after vehicle crosses.

N Special paint to reduce water resistance.

M Inflatable planing board to increase water speed.

Y Use ACV barge, no propulsion system. Carry across vehicle by barge on winch cable.

M Harpoon guns or bazooka to throw line and winches to aid river crossings.

Y Increase buoyancy and stability with air cushion outriggers.

Y Air- or fluid-cushion suspension assist either built-in or add-on kit form for total vehicle weight or partial support.

Y Inflatable balloon pontoons pressurized from central air system.

N Balloon inflation with lithium hydride and water to generate hydrogen.

Y Water jet to wash away river bank.

Y Air cushion bridge-run out sections for water crossing; power source ashore and independent of run-out sections.

N High speed pulverizer kit and jet dispenser to fill craters.

Y Quick-hardening foam cut to fill holes or cut slipperiness, or allow crossing mines, fields.

N Helium balloon kits for soft soil or river crossing.

N Use rocket-emplaced anchor with power winch to repetitively haul vehicles across slippery surfaces.

M Add J.A.T.O. for exiting onto slippery surfaces.

Power Sources

M Cryogenic (superconductivity) motors for small size, large power output.

N Use gun recoil energy to give impulse propulsion to cross difficult obstacles. Use special non-projectile charge.

M Electromagnetic propulsion and suspension.

Y Linear electric motors with ground-laid cable.

Modular Design

Y Design detachable cab pod which can be used as a controller for any vehicle.

Y Plug in; plug out throw away (modular) suspension to reduce weight and ease of maintenance.

Driver Aids

Y Bourden tube-type spring to change spring rate by changing the shape of cross-section.

M Flexible drive shaft for independent suspension to increase wheel travel through elimination of u-joint angular limits.

M Fluidic control devices for automatic terrain sensing springing and damping.

M Mini-Computer for suspension spring and damping control.

Y Boron spring elements (Hi strength, low volume).

Y Inertia control sensing system for suspension to cause it to react in advance of an obstacle.

M Suspension rate adjustable by the driver simply and quickly while moving (dial-the-ride).

Y High wheel travel (more than 12") suspension for small (jeep size) vehicles.

M Control console with push-button operation of the vehicle. Example: 50 mph, 40 mph button.

Y Improved electrically heated windows to enhance visibility.

Y Dry suspension - no fluid medium in the damping element.

Y All rubber suspension - maintenance free, quiet, cheap.

Y Automatically adjustable damping rate controlled by ride severity measurement (automatic tuning away from resonance range).

Y Air over hydraulic suspension system whose characteristic is controlled by the dynamic wheel (road wheel) load variation.

N Controls have pictorial description of use rather than verbal for easier identification.

M Isolated sound proof and vibration free personnel pod or compartment, rejectable for easy, rapid escape. Installable in every combat vehicle to make all vehicles operable by a single person. A command module idea.

Y Control elevation of operator's position for rough terrain, improved observation.

Y Variable height suspension.

Y Highly improved seating with adjustable springing and damping; resilient bump-stops.

N Extendable fibre optics for looking around corners.

Y Variable rate torsion bars to provide mechanical variable rate systems or small compact configuration.

Y Hydromechanical strut as suspension element. Includes newly developed material (elastomesic) to fulfill multiple and partially contradictory measurements which cannot be satisfied with present hydraulic fluids.

Team No. 6

Members:

Nuttall, Chairman
Segel
Frisch
Firer
Van Deusen
Murray
Cantwell

Basic Mission:

Controls

Environments:

Snow
Steep Slopes
Terrain Roughness

<u>Wheel Concepts</u>

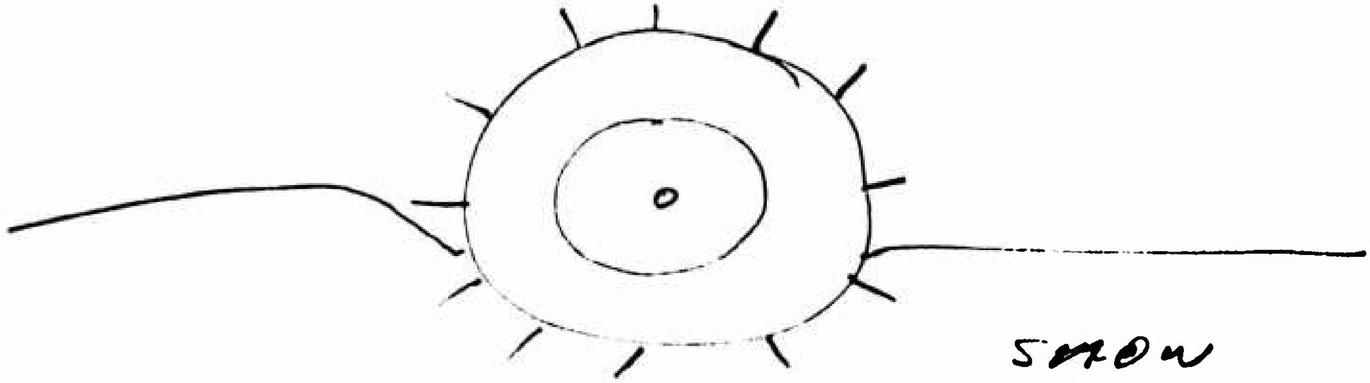
N Tire within a tire: wide outside, narrow inside.

Y Tire with wide cross-section for support on soft soil with raised narrow tread for use on paved roads.

N Tires with wide tread, narrower air chamber to provide side-wall protection (esp. radials) at large deflections.

N Pneumatic tires with periphery shaped to engage and guide a continuous belt that would constitute a track in contact with the ground.

Y Overcome snow by wheel-tire kit that provides aggressive grouser action



M Folding - throwaway tire add-on kit (like passenger car stuff for spares - 1960's).

**Y Build vehicle with central control system to adjust tire pressures up or down as the situation demands - manual, automatic, sensing terrain/tire conditions (no driver intervention).

Y Use slip as a tire pressure control parameter: too much slip, pressure too high.

M Tire with incorporated lubricant that vaporizes an interval from heat build-up when underpressured to increase inflation pressure.

M Spare tube inside tire usually uninflated; inflates on need. Tube in tube; tube inside tubeless tire.

Y Material inside tire that foams when tire is punctured and provided get-home capability.

N Throwaway tire and wheel assembly.

M Changes to snow chains for tires: Add a ladder-type grouser.

N In Tire Damping Capability.

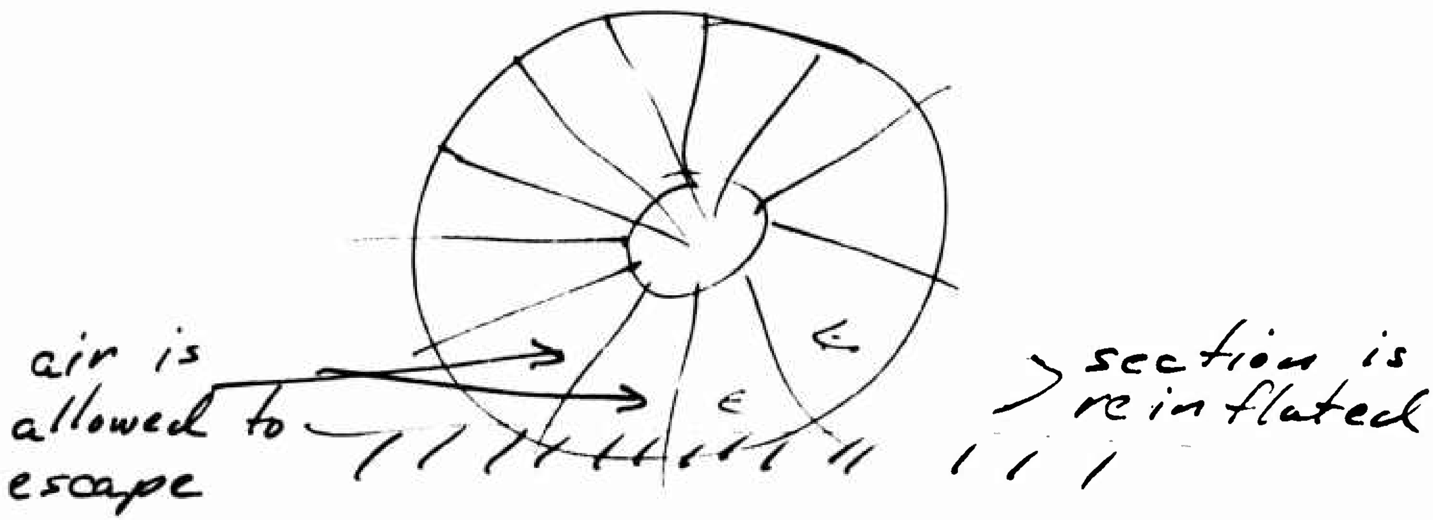
M Rapid changes to tire pressure to change spring rates appropriate to terrain.

N Chambered Tires. Liquid- or air-filled multiple basketball bladders with passive air damping or active air pressure control.

N Wheel discs for tires to provide a springing media within the tire inner bead.

N Segmented tire airchamber for propulsion and damping or segmented tire tube with slip ring cycling.

N Use tires with inflatable compartments:



M Stowed deflated light Rolligon type bags under belly.

Remote Systems

M Remove the driver as a governor. Substitute other more rational sensors.

*Y Provide a small scout or lead vehicle that can be ratio-controlled by a human operator in the following vehicle. Scout vehicle sends picture signal back to a following vehicle or following convoy.

N Remote control with built-in, preset, adaptive program.

N Eliminate the man from the vehicle environment; use remote control from a central point.

Air/Ground Systems

M Carry hydrogen generator or compressed helium in a tank to inflate balloons, etc., to carry vehicles over obstacles, rivers, etc.

N Wing and ground effect combination.

Traction/Flotation Aids

N Simple spade-mobility assist.

M Blow air under the belly of the vehicle to locate suction and reduce drag.

N Combine integral jacking for tire changing with mobility expedient lift.

Y Explosive deployment of spikes within track pad for added mobility.

Y Deployable ice spikes in track guide - inside control.

N Cam operated tracks which can vary drag according to soil conditions and change underway.

M Explosive release of expendable road pads.

*Y Cable loops external to track to give additional loading area when sinkage, also additional soil shear.

N Reduce tire/track motion resistance in soils/snows by vibration - per soil plows.

Y To aid traction, provide a traction control system instead of a throttle to govern engine speed and torque. The vehicle operator would be given guidelines on the shear that the given support medium can provide and the system demands traction accordingly.

Y Develop optimum non-straight path up steep slopes; develop automatic suspension compensation to achieve necessary cross slope; diagonal slope capability.

Y Track with heavy bar studded road wheel tires - studs project through/ between track bars so that on hard roads vehicle runs on tire (stud extensions) rather than on track. No track road pads needed, except for minor noise/vibration control.

N Catspaw ice studs - molded ice - extend under increased interval tire pressure.

M Exploit accelerated age hardening of snow Peter plow stuff.

*Y Suspended Chain Track (SLT variation) - drive for air cushion vehicle used on neutral buoyancy ocean bottom vehicles.

N Direct continuous air-suspended tracks.

M Non-metallic band tracks.

N Generate a wave form in soft soil to propel vehicle forward.

<u>New Vehicle Forms</u>

M Inflatable, Archimedian screws (for Hybrid vehicle use).

M Archimedian screws with built-in jet propulsion units for assist in overcoming obstacles.

N Add features of marsh screw to tracks, wheels, or air cushion to aid in propulsion, increase buoyancy, and lower ground pressure.

N Combine ACV with Archimedian screws for steep slope operation.

N Air cushion lift capacity coefficient to overcome obstacle. Jet thrusters may be a means.

M Trail breaker vehicle for taking groups of standard-wheeled vehicles through deep temperature snows--other than/or an improved snow plow.

Y Hard-coupled vehicles for convoy control.

Y Articulated steering for tracked vehicles, with manual pitch control.

M Articulated vehicle with positive pitch control activated to minimize pitch in second unit. Use motion accelerations, as necessary, from first unit to supply anticipation needed to keep power requirements for joint control to a reasonable level.

N Use large ski-doo type vehicle in snow. Current ski-doo carries only one or two people. Make bigger.

N "Belly Flopper" - pneumatic wave platform for single infantryman (snake-worm motion).

N Jumping Vehicle - energy storage: mechanical, pneumatic, explosive. With automatic jet thrust for flight/landing control.

M Bicycles and trains of bicycles.

M Bekker articulated screw vehicle.

Y Vehicles specifically designed for operation in trains on and off-road, under single driver command or as individual units, as the occasion demands.

External Mobility Aids

M Inflatable pod to encapsulate entire vehicle for river crossing. Possibly a spray-on plastic film.

M Fold down ACV Bridge/Ferry.

M Cable launched from vehicle and anchored by explosive on far side of gap. When also anchored on near side, forms a bridge or aid to gap crossing.

M Control over water by floatable unsinkable ribbons expelled from vehicle similar to child's snake.

M Overcome steep slopes by employing employing emergency reactive propulsion (at least for one vehicle which can then deploy a cable and winch as needed).

M Hydrostatic winch drive with controls to synchronize line speed with track speed regardless of wrap.

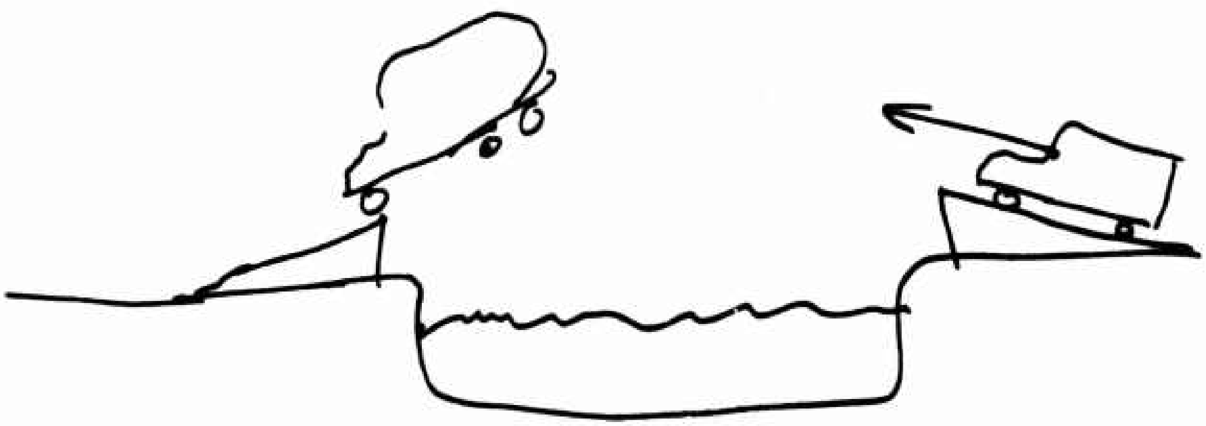
M Storage winch cables to reduce the size and weight of cable and winch.

M Use auxiliary air jets to supply necessary damping - force opposite side in pitch and roll in ACV.

M Look into fast runway bomb - damage repair material/methods for quick terrain modification.

M Use rocket launched line--charge like marines use to clear the beach of mines for clearing vegetation.

N Dynamic launching systems for crossing gaps



N Automatic extension of tension cable which is automatically emplaced and then retracted, ready to be used again on a continuing basis.

N Inflatable bag jack for tire changer.

N Pillow drive-deflated-light stowed under belly. Mobility aid (winch drive?) jacking.

Y Use of solid fuel rockets that can be ignited and shut down at will to provide emergency thrust for times when the vehicle has become immobilized.

N Vehicle with reciprocating saws on forward end to remove vegetation to clear a trail.

*Y Re-examine ACMES vehicle concept for mine clearance and mobility characteristics (MERDC about September 1971).

N Thrusters (jets) to help stabilize vehicle.

M Foam in place bridges/rafts to cross water and soft soil gaps.

N Water impulse systems for external thrust assistance. Use fuel-air mixture to force out water.

M Carry in liquid form an expandable, closed-cell foam to lay down in front of the vehicle for a flotation or mobility aid when foam hardens.

M Inflatable fascines.

Power Sources

M Use of smaller engines, supplemented by energy storage device (e.g., flywheel) to handle peak power demands.

N Gas Pop Gun to accelerate engines.

M Friction Drive System.

N Source of energy coupled with mechanical springs providing an impulse to lift and propel one man through the air.

Driver Aids

M Crew ejection system for tanks.

Y Proper seat belts - restraints.

Y Roll bars for vehicles.

N Active suspension to control roll/pitch.

M Automatic Navigation System based upon area surveillance system which selects path of least mobility obstruction!

N Air droppable navigation aids/sensors with communication link to driver for automatic route optimization.

M Terrain intelligence by satellite to avoid impassable areas.

M Pathfinder vehicle as a terrain sensor.

N Man in ejection return capsule to observe terrain and remotely guide vehicle.

M Use advanced electronic technology to place small computers in a vehicle that determine the optimum suspension parameters for the environment being negotiated. Vehicle has an adjustable suspension.

Y Hook vehicles together in convoy with electrical wires and automatic speed controls.

N Fluidics Technology to be used in design of control systems. (Similar to technology used in Helicopter Automatic Stabilization Systems).

M Automatic Speed Control based upon sensing vehicle motion and/or "forecasting" (sensing) terrain obstacles in front of the vehicle.

M Better performance inclination at driving position - Digital Readout - including sensing of terrain conditions (soil strength, etc.).

N Sensor display systems to driver, including and/or other non-visual senses, such as odor, to provide information on the operating state, e.g., is a component about to fail.

N Eliminate as many control functions as possible by use of automatic shut downs, power limiters or audio warnings.

N Provide control systems that automatically change in character as the vehicle changes from one operational mode to another in a hybrid vehicle.

M Dual driver control - one the big picture, one the close-in, could later be automated. It is postulated that cross-country mobility can be improved by use of two drivers. One driver is concerned with the short-term task of negotiating terrain with the second driver concerned with the longer term guidance and route selection tasks. Provide a control system that permits their control actions to be properly summed.

M Fiber optics in place of vision blocks to extend vision.

M Anticipate mobility conditions ahead of the machine by use of T.V.

M Augment driver vision - high/low line of sight, vision intensifier.

N Simple precheck of vehicle systems for reliability and compare with upcoming mission.

N Driver conditioning (booze?) for greater ride, speed tolerance, faster responses.

N Simple secure distress signal; (not through normal channels). Carry a carrier pigeon on vehicle for release when assistance is required (mated pair - one out, one stay).

N Simple human engineering of controls: brakes, steering gear, seats. Make them adjustable to fit driver's desired response.

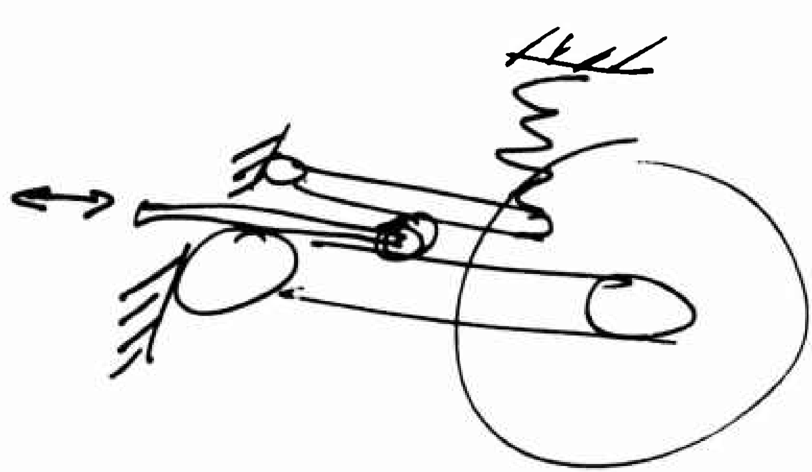
M Design adjustable pedals (brake, clutch, throttle, etc.) for varying leg lengths.

N Encapsulated operator and gyposcopically stabilize him.

Y Relocated operator to be atop vehicle amidships, thus seeing better.

M Active suspension system controlled from sensing vehicle motion and stabilized hull (or body) position - Pitch and Roll adjusted by suspension - Yaw adjusted by automatic steering input, with operator override.

Y Adjustable mechanical rate on suspension spring (Ray MacHenry design).



M Allow a vehicle to follow automatically a preceeding vehicle. Lock on (Light - IR Seismiz) to control speed and/or steering. Alternate - driver indication - of closing rate distance between vehicles. Speed.

M Simple indicator system that tells the driver how far he is behind next vehicle in convoy. Narrow band rear light photo cell forward on vehicle may be automated to red, green, yellow idiot light.

Y Simple control of uncoupled trains/convoys for manpower reduction.

M Siesmic sensors for convoy control.

Y If the vehicle has no suspension, rough terrain traversal can be improved by employing dynamic vibration absorbers, i.e., allow a small mass to displace a large amount at the proper natural frequency.

N Pleasure center stimulation of man and beast with automatic remote or programmed control.

M Design seats more comfortably and easier to adjust.

2 October 1972

APPENDIX H

MASTER AGENDA

MONDAY, October 16

1600-2200 Arrival and check in — Ehrlich, Cantwell and Crane

1600-1800 Briefing of team chairmen — McNeill, Magistro

- Orientation of team chairmen — ground rules of workshop.
- Distribute packages.
- Discuss idea-spurring questions and how to use them.
- Discuss briefing document and objectives of workshop.
- Dry run of typical workshop.

1800- Typing — Between 1800 and 1045 Tuesday, need to type up:

- Idea spurs.
- Improved briefing document.

TUESDAY, October 17

0800-0910 Welcome, Opening Remarks — Ehrlich, Cantwell, Ziem

0910-0945 Workshop orientation and charge — McNeill

- Slide show.
- Handouts.
- Brainstorming procedure.

0945-1015 Break — Coffee and rolls in auditorium

1015-1130 Briefings — Dugoff and Nuttall

- Terrain description.
- Definition of the mobility problem.

1130-1200 Team Organization — Team Chairmen

- Divide into six teams.
- Find rooms.
- Set up work area.
- Distribute first briefing document.
- Supply idea spurs to chairmen.
- Get-acquainted between team members.
- Quick look at problem before lunch (if time allows).

Tuesday, October 17 (continued)

1200-1300 Lunch

Sit by teams.

Continue discussions while waiting to be served.

1300-1430 Workshop Session I

Each team 7-8 members.

Assign an area for each team.

Objective: Idea output of at least 70 ideas per session.

Ideas to be placed on 5"x8" cards.

What are the possible future (1980-1990 and beyond) technological advances which might be translated into an improvement in mobility from a standpoint of:

1. Man/Machine/Environment interface?
2. Vehicle morphology (shape and arrangement)?
3. Traction systems?
4. Propulsion systems?
5. Suspension systems of ground vehicles?
6. Control systems?

1430-1600 Typing up all ideas generated in Session I and distribute them to all participants. Estimate load: 500 lines.

1430-1530 Briefing — Marsh and Patek

Vehicular Components.

1530-1545 Break

1545-1600 Techniques Review — McNeill, Magistro, Panger, Team Chairmen

Review Techniques.

Pinpoint Procedure Weaknesses.

Take Corrective Action.

1600-1700 Workshop Session II

Same teams as Session I.

Review distributed material, especially ideas of other groups.

Seek 90-100 ideas per team.

"In light of the previous briefing and a review of the ideas generated by other groups, what might you add to the list you or other Committees generated in Session I?"

TUESDAY, October 17 (continued)

1700-1730 Critique and Summary (Team Members)

Develop written summary of day's activities.

Critique of technique, methods, procedures.

Organize cards generated into logical groupings.

Suggest pairs of members do each of the three above tasks.

Team Chairmen

Team Chairmen and Steering Committee

Evaluate progress.

Suggest improvements.

Re-define charge.

1730- Typing

Type up and distribute ideas from Session II by 0390 Wednesday.

1830-1930 Get-Acquainted Cocktail Party — University I

WEDNESDAY, October 18

0830-0930 Briefings — Fierer

Soviet Vehicles.

0930-1200 Workshop Session III

Assign 2 or 3 mobility impediments per team.

Looking for at least 200 ideas per team.

Take break at 1030 for coffee and pastry in workshop rooms.

"How might these new technological developments, in coordination with existing technology, be applied to attack the mobility problems presented by:

1. Obstacles?
2. River Crossings?
3. Snow?
4. Soft Soil?
5. Slippery Surfaces?
6. Steep Slopes
7. Dense Vegetation?
8. Urban Areas?
9. Terrain Roughness?

WEDNESDAY, October 18 (continued)

Consider the following approaches:

1. Wheels
2. Tracks
3. Air Cushions
4. Unconventional, novel or new systems
5. Hybrid Combinations of the Above
6. Add-on Kits to the Above
7. External Mobility Aids (winches, portable mats,etc.)"

1130-1200 Progress Review — Team Chairmen and Steering Committee

Turn over last half hour of Session III to Members to continue along.

Half-way progress review and recommendations.

1200-1300 Lunch

Have Teams eat together (less chairmen).

Team Chairmen and Steering Committee eat together to continue discussions.

0100- Typing

Begin typing up results of Workshop Session III.

1300-1345 Briefing — Nuttall

Historical approaches to the Mobility Problem.

1345-1600 Workshop Session IV

Continuation of Session III.

Looking for at least 100 ideas per team.

Last half hour develop evaluation criteria.

1445-1500 Break

1500-1600 Evaluation Briefing — Ehrlich

Team chairmen meet together.

Discuss evaluation technique.

Discuss trade-off technique.

Discuss ranking criteria.

Discuss Army requirements.

1500- Typing

Complete typing up ideas from Sessions III and IV by 0830 Thursday.

WEDNESDAY, October 18 (continued)

1600-1700 Rating Check List — Steering Committee

Reconsider Rating Check – list previously developed.

Select Ad Hoc Team.

1600-1700 Critique — Team Chairmen

General review and critique of program.

1600-1700 Summary — Team Members

Review and organize work of the day.

Prepare a written summary of results.

1700- Have Rating Sheets typed up and run off by 1100 Thursday.

1830- ? Dinner/Theater, Village Barn Theater (optional).

THURSDAY, October 19

0830-1100 Workshop Session V

Same groups as for Workshop III and IV.

Coffee break at 1000 in workshops.

Look for 35 ideas per team.

How may the results of the preceding Sessions be applied to attack the mobility problems associated with the following missions:

1. Logistical (tactical support in the combat area)?
2. Combat (transport of a weapon or combat troops on the battlefield)?
3. Command and Reconnaissance (transport of lightly armed personnel at high speed over a wide variety of terrain)?

Take cognizance of the factors requiring the Army to make multiple usage of its vehicle fleet in a wide range of environment and for the use of each vehicle in general-purpose assignments.

Also consider the pressures of cost, reliability, maintainability, weight, complexity, space, east of operation, etc.

1100-1200 Evaluation Session

Evaluation of concepts employing criteria and score-sheet developed on Wednesday.

1100-1400 Type up results of Workshop V

1200-1300 Lunch

Seating for lunch mixed up -- do not sit by teams.

1300-1400 Workshop Session VI

Same teams as Sessions III-V.

Restatement of the mobility problem.

'What non-hardware approaches may also be suggested to improve the overall operational mobility of our field Army?"

1400-1445 Briefing — Jones

Current Army Vehicle Fleet and Drawing Board Plans.

1400-1700 Type up results of Workshop VI

1445-1615 Workshop Session VII

Same teams as Sessions III-VI.

Idea improvement.

Break at 1500 in workshops.

"Take the best ideas so far presented and see how they might be improved upon."

1615-1700 Report Preparation

Prepare written summary of activities.

Prepare written critique of activities.

Prepare 15-minute presentations for Friday.

Discuss conclusions and recommendations to be forthcoming from workshops.

1830- ? Banquet

<u>FRIDAY, October 20</u>

0830-100 Fifteen-minute team reports — Ehrlich

0830-1200 Type up results of Workshop Session VII, written summaries and critiques.

1000-1015 Break — Make arrangements for return to airport.

1000-1200 Open discussion and development of conclusions — Ehrlich.